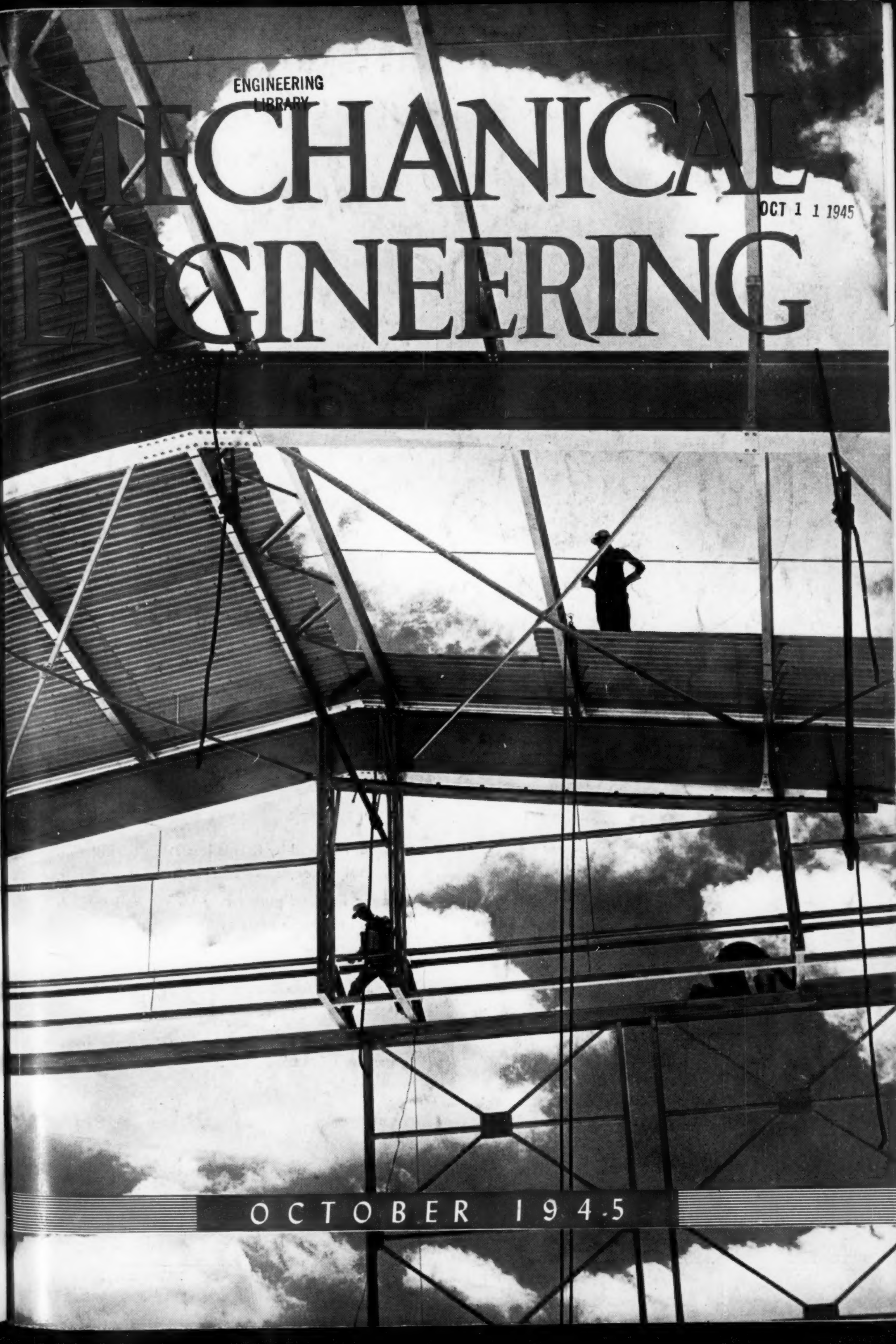
MECHANICAL ENGINEERING



OCTOBER 1945

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 67 NUMBER 10

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Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York 18, N. Y. Cable address, "Dynamic," New York. Price 75 cents a copy, $6.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage outside of the United States of America, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B13, Par 4). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Member of the Audit Bureau of Circulations.

White Hot Steel in a Glass Tube

(Saves furnace time in preparing a slag-free sample for carbon analysis at National Works, National Tube Company. A common 1-ounce rubber bulb fitted to a length of glass tubing draws up metal at 3000 F from a spoonful fresh out of the open-hearth furnace. The old method of preparing a sample involves drilling into a slug of cooled metal, requiring 15 minutes or more.)

Volume 67
No. 10

MECHANICAL ENGINEERING

October
1945

GEORGE A. STETSON, *Editor*

Text for C.E.D.

If THE Committee for Economic Development are looking for texts to define their purposes and methods, they will find several in the Book of Nehemiah. Mourning in captivity over the desolation of Jerusalem, Nehemiah sought and obtained from King Artaxerxes permission to return to his native city for the purpose of rebuilding its walls. After he had viewed the ruins by night he said to his fellow countrymen, "Come, and let us build up the wall of Jerusalem, that we be no more a reproach. . . . And they said, Let us rise up and build. So they strengthened their hands for this good work." Then all the people set to work, "every man over against his house," and when their enemies attempted to stop them, part worked while others stood guard. "So built we the wall . . . for the people had a mind to work."

The walls of our peacetime living have been laid waste and the voice of C.E.D. is the voice of Nehemiah bidding us repair the wall, every man over against his own house. In thousands of communities, co-ordinated by the studies and activities of the Committee, the work of reconstruction has been made a local affair. The proof of success is yet to come and there will be those who would hinder or divert the workers. But the wall will be built if the people have a mind to work.

Throughout the ages men, viewing the dead ashes of their fortunes and ideologies, have reacted to the stimulus of new ideals that have given them new hope and renewed vigor. Thus Aeschylus, in the trilogy of the Oresteia, brooding over "the ancient blinded vengeance and the wrong that amendeth wrong," and seeking a way out of the tangled events of bloodshed and madness that, according to Greek thought, must inevitably flow out of the sacrifices by Agamemnon of his daughter, turned to "Zeus, whate'er He be," and wrote:

> "Zeus the Guide, who made men turn
> Thoughtward, Zeus, who did ordain
> Man by Suffering shall learn.
> So the heart of him, again
> Aching with remembered pain,
> Bleeds, and sleepeth not, until
> Wisdom comes against his will.
> 'Tis the gift of One by strife
> Lifted to the throne of life."

So also Western Europe, recovering from the spiritual and economic oblivion of the Dark Ages, flowered into a resurgence of enterprise and culture animated, as Henry Adams shows, by adoration of the Virgin. The extraordinary cathedrals built to the glory of the power she personified stand today as witnesses of its hold over the men of those times.

Nor is our own history without its testimony of men who discovered powers greater than their own that sustained their pioneering spirit in the New World. The only miracles they experienced were those wrought within themselves. By energy and fortitude they accomplished the task before them, "for the people had a mind to work." So also they founded a Republic, established the arts of agriculture, commerce, and industry, fostered the spirit of independence and liberty, made progress toward the principle of equal opportunity for all, and built up a Mecca for the oppressed peoples of the earth who wished to share the advantages and the manner of life that had here been set up. More blatantly advertised than intelligently comprehended in later years, their ideals of democracy have since flourished in a land rich in resources and opportunity and isolated by distance, indifference, and self-satisfaction against the ideologies, old and new, of other portions of the globe.

Two world wars and a depression have changed all that. The vigorous and immature Republic of the West has emerged as the world's strongest and wealthiest nation, untouched by the material destruction that has been visited upon large areas of the world, envied or hated by many peoples who must look to her for leadership and example. On her more than on any other nation rests the responsibility of maintaining the peace of the world, of binding up its wounds, and of leading men into pathways of hope, of opportunity and personal security, and of better modes of living.

How shall we prepare to do what lies before us? Surely not by building physical walls as did the citizens of Troy and Jerusalem, nor by erecting those figurative walls of selfishness and indifference that shut out more than they shut in. The walls we build must encompass all races and all peoples for common defense against the evils that have plagued mankind since the beginning of time. As the C.E.D. has shown by its method of local attack worked into a national program, the place for everyone to begin to build these walls is over against his own house.

Our problem is greater than the national and material one to which the C.E.D. must obviously limit its leadership. What shall it profit us if we achieve the wonders we have planned and give little thought to the rest of the world? Shall we do nothing to dispel the suspicion or to remove the causes of hate and envy? Shall we do no more than our legal commitments demand to avert the utter destruction of civilization another war would probably bring about, or to counteract what appears to be a trend toward economic serfdom?

The regeneration of inner power may be called mysticism by some hard-headed folk, but faith in it is more potent to aid men in what they have to do than the

starkest kind of realism has ever done. Men call it by different names, but engineers recognize one phase of it in the fructifying force of scientific knowledge. It was Pallas Athena, Goddess of Counsel, who, in the third drama of the trilogy, broke the power of the Furies and rescued Orestes from his madness. So in a modern sense, Science may save the world from its madness if men who love the truth are sufficiently stirred by their convictions to let Science do for us what it will. Then it may be said of us, "So built we the wall, for the people had a mind to work."

More Fundamentals

IT IS TO BE hoped that Dr. von Kármán's little article, "Atomic Engineering?" will provoke discussion of his ideas, for the subject is one which is important to the engineering profession.

Trends in engineering education before the war were in the direction of placing greater emphasis on fundamentals and in supplementing the technical-scientific stem of subject matter with studies for engineers in the nontechnical and social-science fields. The war itself developed two great immediate needs which the universities and engineering schools were called upon to meet. One of these needs was for men of science who had the knowledge and imagination to exercise their special talents in many ways, including the application of scientific principles to the development of new devices and weapons that would keep us at least one lap ahead of our enemies. Radar and the atomic bomb are spectacular examples of what was accomplished. Attention of scientists to these tasks played havoc with many of the research and teaching organizations of our universities in several important ways. Much fundamental research was interrupted, faculties and research staffs were broken up, and the education of scientists on whom the burden of the future is to fall was largely abandoned.

The other great need was for technicians to carry on modern warfare which depends heavily on mechanization on the land, on the sea, and in the air. Engineering education suffered particularly because of this need. With the notable exception of certain phases of the Navy program, lack of time and the demand for training in relatively narrow fields of technical skills, made necessary the abandonment of emphasis on a broad basic training in fundamentals and switched programs in the direction of those of the technical-institute type.

Today, the engineering colleges face a stupendous task and a provoking challenge. They must reassemble their faculties, re-establish their curricula, and be prepared not only to go forward with the interrupted education of men who were called to the colors but also to educate the younger men who elect to study engineering. It is essential therefore that programs, methods, and objectives be given thorough study and that each school take some decision as to the part it will play in the work of reconstruction.

This is not the time or the place to discuss general education at all intellectual and age levels which is an important subject rightfully engaging the attention of all civilized nations. What most concerns engineers and the engineering colleges is the kinds of education that should be made available to those who are to enter the industries they serve. To the public-school system, the trade schools, and many of the industries themselves falls the task of education for a considerable portion of the people employed in those industries. To these agencies also must be added the technical institutes if for no other reason than the fact that the Engineers' Council for Professional Development recognizes a distinction between technical institutes and engineering schools and colleges.

The universities and the engineering schools and colleges provide education for a much smaller but a very important number of the employees of industry. Today —and probably it will be more so in the future—most, though not all, leaders of industry have acquired their preliminary education in the universities and engineering colleges, and there is a hopeful trend toward supplemental education at this level of men already filling responsible posts or seeking advancement in that direction. While much of this education, particularly in the professional schools, is vocational in character, it is generally true that it is the nonvocational aspect of higher education that most fruitfully develops latent talents for leadership and attainment.

It is the task of the engineering college to train two great types of men. They can safely leave to the technical institutes the training of competent technicians who play such an essential role in modern civilization. But they have the responsibility of seeing to it that the best educational foundation is afforded those who are destined to fill many of the administrative posts in the industries based on engineering, and they have a much more important and almost unique responsibility in the training of those creative and analytical minds on which the development of engineering itself depends. Dr. von Kármán's comments undoubtedly apply with greatest force to the education of this second group.

If the present functions and objectives of the engineering colleges are to be retained, and it is important that they be retained, not all young men who can be usefully educated in engineering would respond favorably to the changes Dr. von Kármán proposes, nor would all engineering colleges be able to attract teachers of the caliber necessary to carry out the task he sets for them. But these are not reasons for refusing to attempt the raising of the quality of teaching or for revising the methods by which the fundamentals of engineering are taught. A process of natural selection operates when young men choose to specialize in physics rather than engineering, a selection influenced by differences in aptitudes and interests and the careers which lie beyond in commercial and more or less academic ways of life.

In spite of all these differences and apparent difficulties there remains the tantalizing speculation that Dr. von Kármán's ideas on education in the fundamentals might work with a majority of engineering students, if they were exposed to them, with gratifying results all along the line. If they were put into effect they would certainly afford added justification for considering engineering a learned profession. If they succeeded in increasing the number of original contributions of the engineering profession, they would do much to improve the economic conditions under which the world must live and would aid in maintaining peace.

CREATIVE ENGINEERING *and* PATENTS

By A. A. POTTER

ACTING PRESIDENT AND DEAN OF ENGINEERING, PURDUE UNIVERSITY, AND EXECUTIVE DIRECTOR, NATIONAL PATENT PLANNING COMMISSION
PAST-PRESIDENT A.S.M.E.

OUR entire social structure has been altered during the last century by inventors who are the constructive builders of our civilization. These inventors opened new frontiers and opportunities for abundant life *not* by depriving people and nations of their property rights through robbery, trickery, and offensive warfare, but by creating new wealth in the form of new materials, new processes, new devices, new industries, more economical manufacturing methods, and new products.

A.S.M.E. CONCERNED ABOUT INVENTIVENESS

Recognizing the importance of creative ability in the years ahead, The American Society of Mechanical Engineers, under the inspirational leadership of A. R. Stevenson, Jr., has held, since November, 1942, a series of discussions emphasizing the importance and methods of enhancing ingenuity and inventiveness. These discussions brought out the following matters of special interest to the engineering profession as well as to the public at large:

The art of inventiveness may be the result of logical scientific thought and tireless experimentation or it may depend on intuitive insight. Intuition appears to be the innate ability of some inventors. The inventor at times finds a correct solution or creates a working mechanism based on laws not known at the time the discovery was made. Intuitively, some inventors are able to foresee correctly the future and its requirements and to arrange and direct their efforts accordingly. Men of genius have, upon occasions, created correct theories or made true discoveries long before enough tangible evidence had become available to justify their assumptions. Intuition on the part of Leonardo da Vinci enabled him to show in his paintings and writings certain details in accord with scientific data and discoveries which were unknown in his time. To encourage creative endeavor inclusive emphasis upon logical thinking should not be carried to such a degree as to neglect the use of intuition. Insight is the father of invention far more indisputably than necessity is its mother.

Inventors can be made and creativeness can be developed by proper education, training, and environment. Those who invent differ from others not in the *kind* of experience, but in their *attitude* toward it. The inventor is constantly curious about the reason why and how a device works and has a definite interest in improving it. Inventiveness requires, in addition to scientific knowledge, also good reasoning power, constructive discontent with things as they are, recreative imagination, diversified experience, curiosity, resourcefulness, open-mindedness, industry, perseverance, and optimism.

In education, machinery must be set up to stimulate the inventive faculty where it is found: An environment must be provided so that creativeness can go on unhampered and under conditions which will allow the formation of as many images, as many hypotheses, as many suggestions as possible. More of the teachers' time and talents should be devoted to the most gifted students. Greater opportunity for creative work should be provided in the elementary schools as the earmarks of ingenuity appear early in life and should be developed to the utmost. More use should be made of "hobby shops." Creativeness cannot be developed by causing the individual to memorize, to repeat facts, to take examinations, to prepare for some higher level of education or for some specific outlet. Creativeness must be a part of the procedure of the teacher. Creative-design programs for engineering-college graduates, developed in some industries, should be extended to others and such programs should be used more generally in engineering colleges, particularly in the more advanced and graduate instruction. Association with masters who can provide inspiration so vital in creative endeavor can be brought about by a more general mating of pupil and master in schools as well as in industry. Creative teachers in schools and colleges and creative executives in industry are needed to develop creativeness in the youth of our land.

The inventor must be equipped with scientific knowledge which is an indispensable tool in research and other creative endeavor. At the same time, he must continuously protect himself against the encroachment of custom and habit and must have the capacity to construct bold, effective, and varied concepts out of the clues which lie concealed in scientific and technological problems.

Environment and the form of government account for the fact that Europeans—not nearly as inventive in Europe as the Americans—have produced in this country a Steinmetz, a Pupin, a Baekeland, and a Sikorsky. These men of genius would probably never have achieved the inventions which America brought forth from them had they remained in their native environment. This country is responsible for most of the epoch-making inventions of our times because the American Revolution and the Constitution to which it gave rise emphasized and idealized the rights of the individual above those of the State. The American patent system which was established in 1790 under the Constitution of this country emphasized the rights of the individual and hence is consistent with the theory of government under which our country has attained its greatness. Our patent system, stimulating the creative talents of our people, is largely responsible for the industrial supremacy of America and for the high standards of living of its people. Our patent system guarantees to inventors and to those who invest in inventions far greater protection than that of any other country, and under it the best and the largest body of inventions in the world has been developed.

Another factor which has contributed to the creativeness in this country is that in America, more than in any other country in the world, along with the enterprise to create, there is also a willingness to discard a satisfactory present in order to create a better future. Rapid obsolescence engenders invention. Still another factor is the process of "Yankee ingenuity" which originated from the environment of the early settlers which forced them to invent or starve.

Contributed by the Committee on Education and Training for the Industries and presented at the Annual Meeting, New York, N. Y., Nov. 27–Dec. 1, 1944, of The American Society of Mechanical Engineers.

FIRST REPORT OF PATENT PLANNING COMMISSION

For nearly three years the National Patent Planning Commission has been appraising our patent system to make certain that it is operating most effectively in the public interest, keeping in mind that any changes in the patent system must increase maximum incentive to the inventor and definite encouragement to those who develop inventions into marketable products. In the first report which was released in June, 1943, the Commission confined its recommendations to the mechanics of patent law and the use of patents. Among the findings and recommendations in this report the following are significant:

1 The protection afforded by our patent system has aided our war effort by bringing about a free and complete exchange of scientific and technological knowledge and the products of inventive genius between our industries and our government.

2 An investigation of the factors which justify the nonuse of patents and of the various charges of suppression, which has been given general publicity, indicates that American industry is not guilty of suppression of patents to any significant degree. Nonuse does not necessarily involve the suppression of a patent. Patents are often shelved pending financial, commercial, or technical development, but a patented article or process for which there is a substantial public demand will not be long kept from the market.

3 Compulsory licensing of patents may have some justification as a measure of self-defense in countries of limited natural and human resources, or in those lands which have a major portion of their industries under foreign control, or in countries which have a considerable portion of their patents granted to foreigners. Our country has great creative genius and a fair abundance of natural resources during normal times. Our industries are under American control, and about seven eighths of the patents issued by our patent office are granted to citizens of this country. Thus a general system of compulsory licensing is undesirable for this country from the standpoint of public good.

4 While the Commission does not favor a broad compulsory patent-license system for our country, it has recommended that a public register be established in the Patent Office on which patents could be entered upon the request of their owners, with a statement of the terms on which a license would be granted. It is believed that this system, called in British patent law, "licenses of right," may aid individual inventors in finding means for exploiting their inventions.

5 Patent cases have represented less than ten per cent of all antitrust cases during the past fifty years and are therefore not a major contributing factor to unfair competition in restraint of trade. At the same time, patents may be and have been used in a manner detrimental to the public. The abuse arises not from the patent itself but by virtue of secret, improper, and even illegal agreements. The Commission has, accordingly, recommended the compulsory requirement for the recording of all agreements so that they will be available to the public, to governmental agencies, and to congressional committees.

6 During recent years, certain courts have ruled that a patent should not be granted if the invention is the result of "the slow but inevitable progress of an industry through trial and error." Even more significant was the opinion announced by the Supreme Court on Nov. 10, 1941, that "the flash of certain genius" must be revealed to justify a patent. The "flash of genius" yardstick is influencing the courts in a manner which is detrimental to the granting of patents for important improvements and for new devices and processes which are the result of research, experimentation, and development. The National Patent Planning Commission has recommended that Congress, by legislative enactment, declare a policy that "patentability shall be determined objectively by the nature of the contribution to the advancement of the art, and not subjectively by the nature of the process by which the invention may have been accomplished."

7 The provision of an objective yardstick for determining the existence of an invention must be followed by a uniform application of the yardstick. Seldom is an issued patent declared invalid by a court on the basis of the same facts and records known to the Patent Office at the time of the patent grant. To insure that the test of invention is applied in a uniform manner, the Commission has recommended that "whenever the validity of a patent is attacked in an infringement suit before a district court, the court shall certify the record to the Patent Office for a report on the validity of the patent," this report to be advisory only.

8 The Commission also favors that the jurisdiction of the existing Court of Customs and Patent Appeals be expanded, so that it functions as a single Court of Patent Appeals, receiving and deciding appeals from all the district courts in patent cases.

9 Public interest requires the avoidance of deliberate delays after a patent application is filed. A proposal of long standing, favored by the Commission, is that a patent monopoly shall not endure more than twenty years from the date of its filing in the Patent Office. This plan allows three years for prosecuting an application to allowance.

SECOND REPORT OF PATENT PLANNING COMMISSION

The second report of the National Patent Planning Commission deals with the administration of patents which have come to be owned outright by the Government and also with the respective rights of the Government and its employees and contractors in inventions involved during the employment or contract relationship.

Realizing that there exists a need for an adequate central source of information as to patents or rights under patents held by the Government, the President of the United States, acting upon the recommendation of the Commission established in the Patent Office, by Executive Order No. 9424 of Feb. 18, 1944, a register of government-owned patents, and the work of registration of such patents is nearing completion.

The Commission has concluded that the general policy of the Government should be that of making its patented inventions available for commercial and industrial exploitation by anyone, but the Government should have the power to grant exclusive licenses or otherwise to dispose of patents under appropriate conditions and safeguards whenever it is determined that such action is necessary to assure the commercial development of an invention of a Government-owned patent.

The Government legally stands in the same relation to its employees in regard to inventions developed by the latter as do corporate employers. Accordingly, the Commission has concluded that it should be left to the agencies of government initially to determine the action which will best serve the interests of the public, the Government as represented by the agency, and the encouragement of inventiveness by the employees. The Commission has, however, recommended that policies and regulations adopted by any agency should be submitted to a central control body for approval before they become effective, and that this body serve as an appellate tribunal with power of final decision as regards appeals which employee-inventors may desire to take from agency decisions.

While the Commission is of the opinion that it is not feasible to have uniform practice with regard to patents resulting from Government sponsored research, it believes, however, that, since the Government has no need of the right to exclude, conferred by a patent, and does not enter into ordinary commercial enterprises in competition with its citizens, full ownership of patents should not be asserted by the Government. An exception to this policy would be the situation in which private ownership of patents would conflict with national interest.

(*Continued on page 679*)

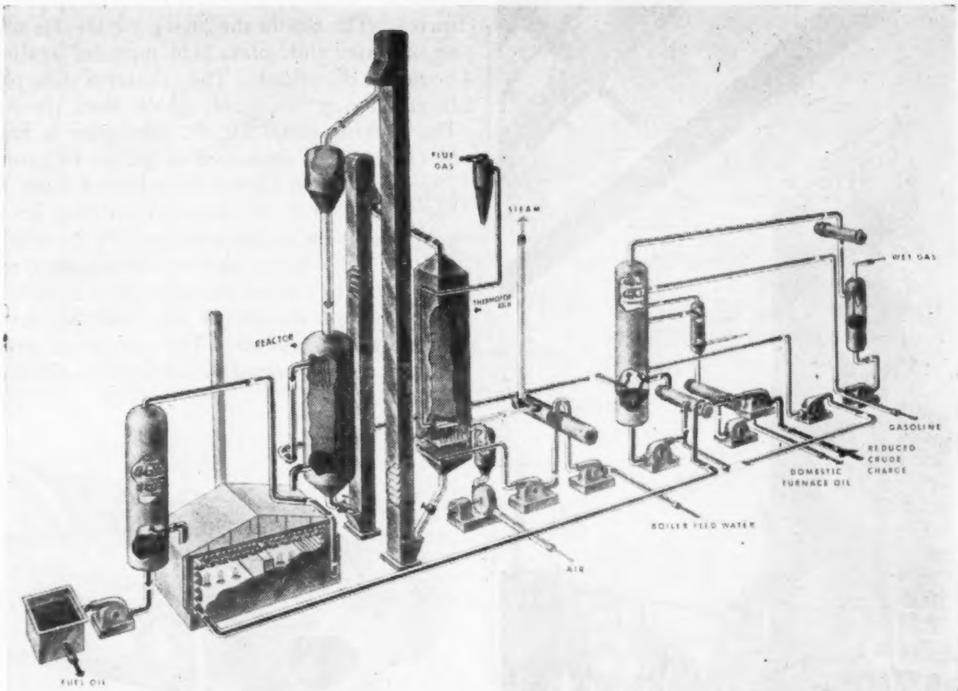


FIG. 1 THERMOFOR CATALYTIC CRACKING PROCESS

HOT-CATALYST ELEVATORS

Some Mechanical Aspects of Elevators Used in Thermofor Catalytic Cracking Units

By STANLEY M. MERCIER

CHIEF ENGINEER, JEFFREY MANUFACTURING COMPANY, COLUMBUS, OHIO. MEMBER, A.S.M.E.

IN the Thermofor catalytic cracking (T.C.C.) process, bucket elevators serve the basic and important purpose of maintaining catalyst circulation between the reactor, where cracking is accomplished, and the Thermofor kiln where the catalyst is regenerated by burning off deposited coke. Fig. 1 shows the essential elements of this process, and Fig. 2 is a view of a typical plant.

To date sixteen such plants have been built to operate a total of 30 T.C.C. units whose combined rating is 330,000 bbl per day. Sixty-two elevators are continuously handling a total of 300,000 cu ft or 6800 tons of catalyst per hr.

These elevators have a maximum height of 201 ft 3 in. centers and operate at ambient temperatures within the casings of approximately 900 F continuously for time intervals which have sometimes exceeded 5 calendar months. In so doing they have advanced the boundaries of proved materials-handling practice in three particulars, viz, extreme height, high ambient operating temperatures, and long continuous operating periods.

Various materials-handling means were reviewed at the outset of this program, and the conclusion was reached that the best and most reliable means of circulating catalyst would be a bucket elevator employing two strands of suitable chain and a continuous system of buckets. No precedent existed for many of the unusual features, such as height, temperature, and reliable continuous performance, and the experimental quality of the undertaking was fully appreciated. The quality of construction of these elevators is recognized as such that they are the only major mechanism in the unit which is not provided with a spare.

Two sizes of units have been built employing correspondingly different size elevators. Units whose nominal charging rate is 10,000 bbl per day have elevators designed for a capacity of 100 tons per hr of catalyst, while 15,000-bbl units have elevators 50 per cent larger and therefore handle 150 tons per hr. The design contemplated that the catalyst might weigh anywhere between 40 and 50 lb per cu ft. In subsequent discussion, any dimensions stated will refer to the smaller of these two elevators since they are the more widely used.

ELEVATOR DESIGN AND CONSTRUCTION DETAILS

Because of the extreme height and temperature, it was apparent that chains of conventional type were inadequate, and a welded construction was adopted to minimize tare weight by employing the high tensile strength of rolled alloy steel, and the integral character of a cast link. Quick tests were extemporized for exploring the field of high-temperature materials to secure the most suitable combination for wear as a chain joint. This resulted in the selection of a nickel-chrome-iron

Contributed by the Refining Subcommittee, Petroleum Committee, of the Process Industries Division and presented at a meeting of the Metropolitan Section, New York, N. Y., May 10, 1945, of The American Society of Mechanical Engineers.

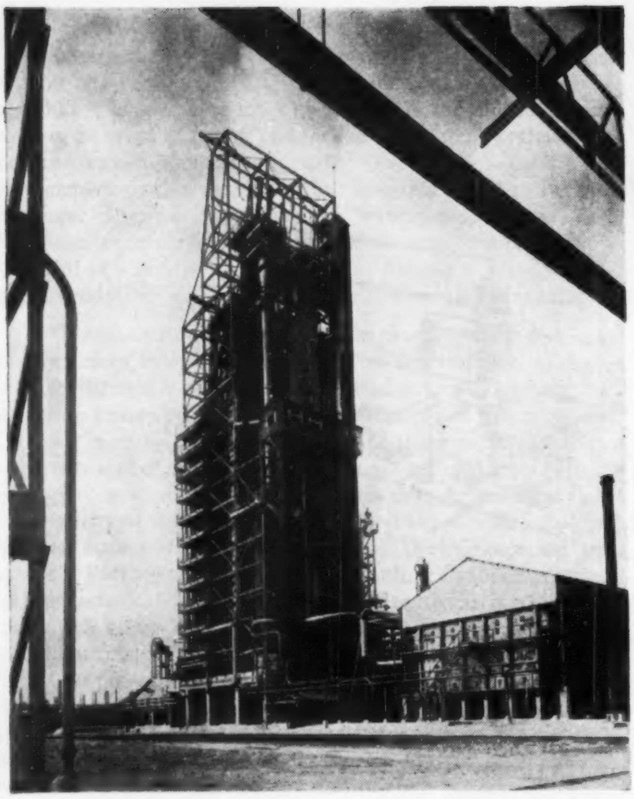


FIG. 2 TYPICAL THERMOFOR CATALYTIC CRACKING PLANT

bushing specially heat-treated to work with a medium-chrome-moly heat-treated pin. The finished chain weighs between 25 and 26 lb per ft and has an ultimate strength of over 200,000 pounds. In a double-strand elevator of this height, it is most important that the chain shall be extraordinarily accurate in pitch and wear uniformly so that the two strands shall be of equal length and maintain this equality during their life. Deficiency in this regard would produce early fatigue failure of bucket ends. The chain shown in Fig. 3, as a cutaway single link, and Fig. 4, as a section of chain and buckets, has demonstrated itself most successfully in discharging all requirements at a speed of approximately 100 fpm.

Fig. 5 shows the general arrangement of a typical elevator structure. The casing, which is insulated on its inside, is an articular system of short panels free to expand individually. This casing is contained in and supported by an independent exterior tower not directly exposed to heat and carried free from the main T.C.C. structure, except for wind and earthquake support. Within the casing, the elevator chains are completely enclosed in guides. These guides are in short lengths equivalent to the casing panels which support them in such fashion as freely to allow differential expansion.

As the elevators must be gastight in the presence of slight pressure or vacuum and must exclude all air, the head and foot shafts are brought outside the casing through conventional packed stuffing boxes. These boxes, however, are devised so as to accommodate such slight warpage or differential expansion of casings as may occur. The detail of this is shown in Fig. 5. As packed boxes stay tight only to the extent they are maintained so, and as the elevator heads are usually under slight pressure, and as the gas atmosphere of kiln elevators is corrosive, the head shafts are provided with stainless sleeves in the packed area where temperatures are conducive to corrosion, and the packing-box parts themselves are of aluminum bronze.

The seals for the foot shafts posed a problem and produced a somewhat complex solution. The relative expansion of the chains was estimated at 16 to 18 in. which, added to wear allowance, dictated an automatic take-up provision for 33 in. of travel. The slot in the casing which this requires is closed by an insulated slide plate held outward against a packed frame by means of springs. This insulated slide plate is carried by a trunnion ring and guide block from the foot-shaft bearing. The packing gland for the foot shaft is built into the guide block which is contained in guides to insure vertical travel. The foot shaft is carried on a braced frame whose appearance has gained for it the name of walking beam. This frame is held positively square and level by a roller pivot shaft, controlling two corners, and by cables counterweighted through a jack shaft, to control the other two corners.

Foot wheels are smooth rim (without teeth) and are split to facilitate maintenance. The spokes are articulated to avoid thermal stresses caused by temperature differential between hub and rim.

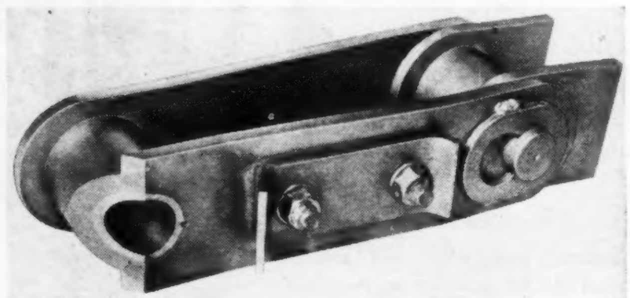


FIG. 3 CUTAWAY VIEW OF SINGLE CHAIN LINK

FIG. 4 SECTION OF CHAIN AND BUCKETS

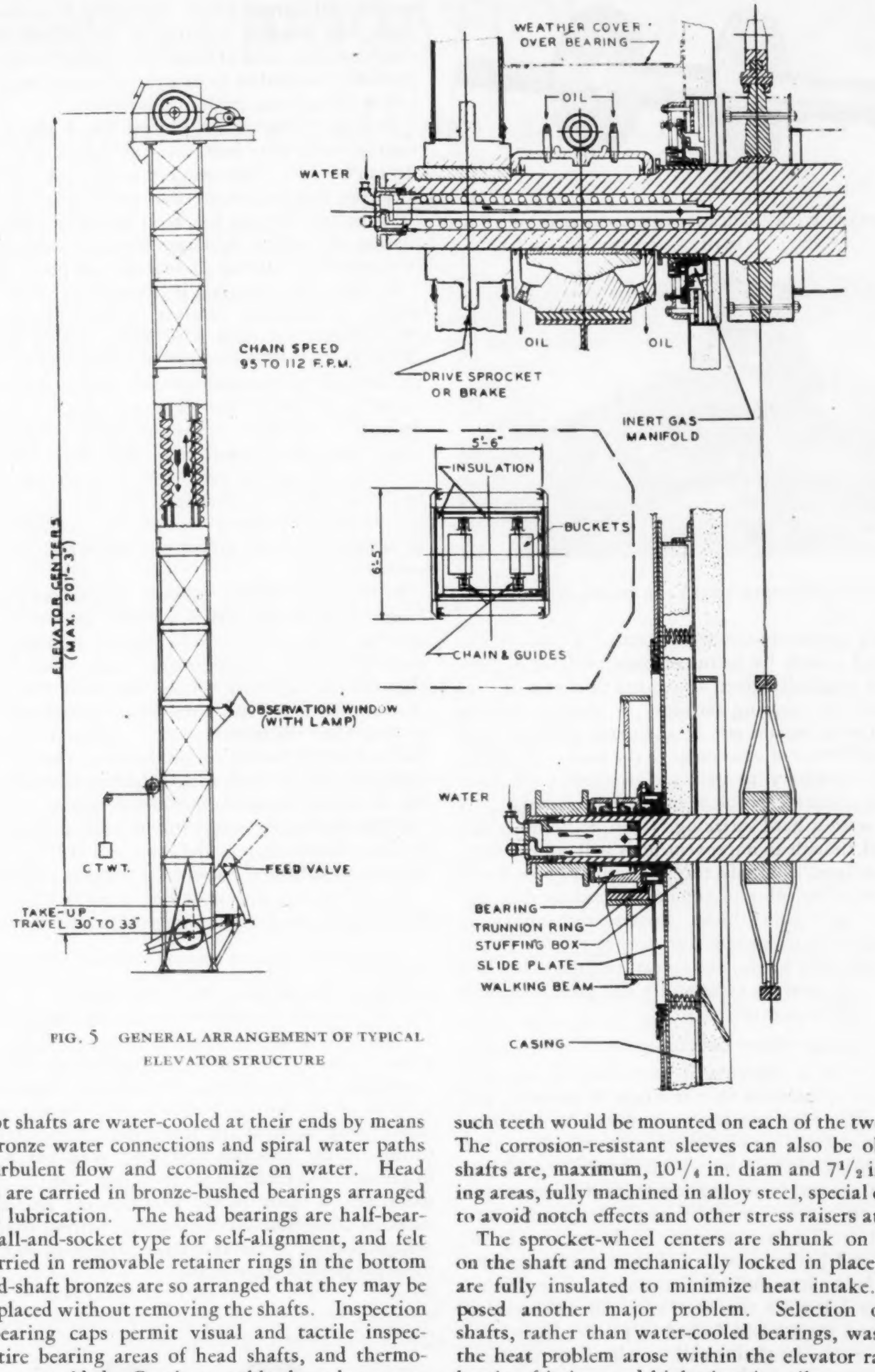


FIG. 5 GENERAL ARRANGEMENT OF TYPICAL ELEVATOR STRUCTURE

Head and foot shafts are water-cooled at their ends by means of stationary bronze water connections and spiral water paths to establish turbulent flow and economize on water. Head and foot shafts are carried in bronze-bushed bearings arranged for positive oil lubrication. The head bearings are half-bearings only of ball-and-socket type for self-alignment, and felt oil seals are carried in removable retainer rings in the bottom half. The head-shaft bronzes are so arranged that they may be removed and replaced without removing the shafts. Inspection openings in bearing caps permit visual and tactile inspection of the entire bearing areas of head shafts, and thermocouple details are provided. Bearing troubles have been completely absent despite the unconventionally low shaft speeds and moderately high mechanical bearing pressures.

SYSTEM OF ELEVATOR DRIVE

The drive consists of an American Standard roller chain to a speed reducer and motor on a drive support which is carried directly off the elevator tower. A differential band brake is employed to prevent reverse rotation of a loaded elevator when stopped.

Fig. 6 shows a head shaft with sprocket-wheel centers without teeth, and Fig. 7 shows a single removable tooth. Nine such teeth would be mounted on each of the two wheel centers. The corrosion-resistant sleeves can also be observed. These shafts are, maximum, $10^1/_4$ in. diam and $7^1/_2$ in. diam in bearing areas, fully machined in alloy steel, special care being taken to avoid notch effects and other stress raisers at critical points.

The sprocket-wheel centers are shrunk on raised landings on the shaft and mechanically locked in place, and the shafts are fully insulated to minimize heat intake. These wheels posed another major problem. Selection of water-cooled shafts, rather than water-cooled bearings, was preferred since the heat problem arose within the elevator rather than from bearing friction, and high-viscosity oils were required for the slow speeds (10 to 12 rpm). This in turn established a thermal gradient and consequent thermal stresses in the shaft and wheel centers, and in the latter assumed notable proportions. The wheel rim may be expected to be 250 to 300 deg F hotter than its bore and would experience stresses prohibitive from a "creep" standpoint. Among several speculative solutions, it was elected to offset these stresses by building these wheels of several concentric disks or rings shrunk together so as to compensate for thermal stresses by prestressing of reversed character. This novel solution has proved entirely efficacious.

With sprocket wheels constructed as described, it is clearly

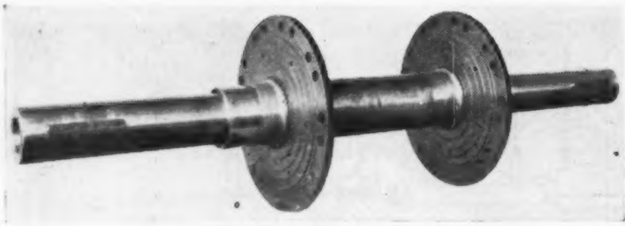


FIG. 6 HEAD SHAFT WITH SPROCKET-WHEEL CENTERS, WITHOUT TEETH

FIG. 7 SINGLE REMOVABLE TOOTH FOR SPROCKET WHEEL

desirable to have separately renewable teeth. These are carried on the wheel centers by means of pairs of drive fit pins. These teeth were originally given a nominal thickness of hard surface alloy on their wearing surfaces. It was the general expectation that wear would not be a serious problem, and there was some difference of opinion as to the need of the hard-surfacing at all. Contrary to expectation these teeth have proved the most obdurate problem in the entire design. A modified design with a hard surfacing $^3/_{16}$ in. to $^1/_4$ in. thick was produced and, though an improvement, is still not enduring enough to be dismissed as satisfactory. Teeth are now being made with a hard-alloy inlay of thickness, graduated to the wear demand, up to $^{11}/_{16}$ in. thick. Because such alloys are all extremely brittle, it is conventional to not employ thicknesses much greater than $^1/_8$ in., and special technique has had to be worked out to produce successfully the present designs which wil shortly be in service.

TRACTION DRIVE DEVELOPMENTS

The high rate of wear experienced on surfaces of sprocket teeth provoked the speculation that it might be possible, and better, to drive these elevators by traction and to eliminate teeth. From a mechanical standpoint this would require that the friction coefficient of chain on wheels should be sufficient to develop traction, and that any tendency for one chain to get ahead of the other would be immediately and automatically corrected. Traction wheels, as shown in Fig. 8, have been made and put in service and these mechanical requirements have been successfully demonstrated. The tires on these wheels are a hot-work tool steel carefully machined to equal diameters and shrunk and locked in place. Steps have been taken to make sure the chains will keep lined up together. Traction wheels are of such diameter that the wear is distributed around their entire periphery, whereas with sprocket teeth this wear is strictly localized. Also the relative slip of chains on wheel surfaces is far less than when teeth are used (as each tooth engages the chain all links in contact must slip forward by a small amount). For these reasons there can be little doubt that wear on traction wheels will be less than on teeth. Since the cost of traction wheels also is less, it would appear that they constitute a satisfactory solution.

OPERATING EXPERIENCE

In the design, construction, and operation of these elevators, we have all learned a lot. Excepting in the matter of sprocket teeth, the troubles experienced have been self-evident as to their correction and of relatively minor character so that we are probably justified in feeling the elevators are a proved success, and in taking some pride in this feeling.

Because of the unusual character of these elevators, three unusual steps have been taken in reference to their operation. An engineer has been assigned to observe and study their performance and investigate any weaknesses. A uniform system of inspection reports has been installed. Exchange of information gleaned by these two means is accomplished by means of a system of bulletins circulated to all plant operations.

Considerable interest is evinced in the horsepower required for handling catalyst in these elevators. The 200-ft elevators are equipped with 40-hp motors but consume only 31 to 32 hp. For elevators of lesser height, the horsepower consumed is proportionately less so that the total for two elevators in a typical unit is about 56 hp. If efficiency is expressed as the ratio of the pure horsepower of lift over the total horsepower consumed, then these elevators have an efficiency of about 65 per cent. As this condition is quite uniform and closely predictable, the rate of catalyst circulation is determined by observation of power consumed and indicated by wattmeters in the elevator circuit which are installed in the control rooms.

In the earlier plants, catalyst circulation was controlled by means of butterfly valves installed where convenient in the catalyst ducts. In the later plants, however, this has been accomplished by "chopper gate" valves installed immediately ahead of the elevators. These valves have more uniform flow characteristics, are less prone to stick, and show less tendency to wear than the butterfly type They also insure that elevator buckets are loaded uniformly across their width. They are equipped with air-operating cylinder, manual volume control, and means for manual emergency operation.

Other conveying equipment is used around these units for handling fresh catalyst and dust, but this is of fairly conventional type calling for no special remarks at this time.

In closing, the author wishes again to thank all those who have so ably assisted and supported him in this undertaking.

DEVELOPMENT MADE POSSIBLE BY INDUSTRIAL CO-OPERATION

Before closing this brief presentation of the mechanical aspects of elevators used for circulating catalyst in the Thermofor catalytic cracking process, it is appropriate to recognize some of those men who have contributed most toward their evolution. These include Mr. George Dunham and his associates in the Socony-Vacuum Oil Company who have had unwavering faith in the feasibility of the elevators; R. R. Collins of the Lummus Company, who has been a constant inspiration and leader in his thinking; and the executive representatives of many of the participating refineries who have supplied constructive criticism and helpful suggestions. The success of these elevators is due to the co-operative effort of all these people and their staffs.

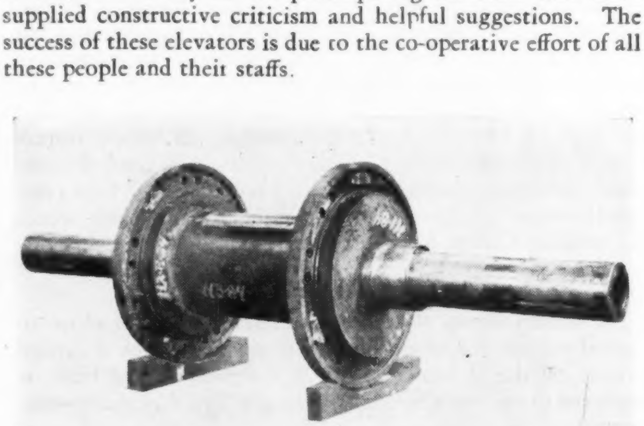


FIG. 8 TRACTION WHEELS FOR ELEVATOR DRIVE

GREASE LUBRICATION *of*

Ball-Bearing Motors and Generators

By EDWIN M. HIGGINS

MASTER LUBRICANTS COMPANY, PHILADELPHIA, PA. MEMBER A.S.M.E.

GENERAL CONSIDERATIONS

SIXTY-FIVE per cent of all electric motors and generators manufactured today are equipped with antifriction bearings. This is a conservative estimate, and the favorable ratio of antifriction-bearing-equipped units to those equipped with sleeve-type bearings is increasing. Based on this estimate, it is evident that the lubrication of antifriction bearings is of universal interest. It is the purpose of this paper therefore to submit for consideration the general concepts of grease lubrication as applied to electric motors and generators although in many cases these concepts may be applied to other applications of antifriction bearings as well.

Why Grease Lubrication? The question is often raised as to the advantages and disadvantages of grease versus oil lubrication for antifriction bearings. It is recognized that each has advantages and disadvantages. Grease lubrication permits simplified bearing and housing design, ease of lubrication retention, versatility of mounting position, and, last but not least, the ease of maintenance. These have resulted in lower-cost equipment, cheaper installation, and more economical maintenance. This has caused grease lubrication to be used in all but the most unusual applications, and lubrication research is mainly directed toward the replacement of oil by grease in all applications.

Causes of Bearing Failures. The causes of bearing failures may in general be grouped as follows:

1 Poor bearings, that is, design, workmanship, and materials of the bearings themselves.

2 Faulty equipment caused by poor design, workmanship, or materials of the equipment to which the bearings are applied.

3 Misapplication of bearings, apparatus, or lubrication.

4 Bearing overloads caused either by careless operation of the equipment or the failure of some other part of the apparatus system.

5 Lubrication failure or bearing contamination, in both cases caused either by faulty lubricating materials, careless maintenance, or overhaul.

Since lubrication cannot correct conditions which exist as a result of causes 1, 2, and 4, only causes 3 and 5 will be considered in this paper. Cause 3 will be dealt with only where misapplication of lubricants is concerned. Cause 5 will be considered in the light of maintenance and overhaul and, to a certain extent, trouble prevention by inspection of lubricating materials.

SELECTION OF GREASE

In general a grease should be selected with the following taken into consideration:

1 Size and type of bearing and housing construction.

2 Speed of operation.

3 Ambient operating temperatures, or temperature range.

Greases may be typed in many ways, namely, type of soap base, viscosity of oil, relative consistency, quantity ratio between oil and soap base, melting point or drop point, and so on through the entire list of chemical and physical properties of the grease.

It might be well to discuss some of the commercially available types relative to their chemical and physical properties since many of these properties play an important part in the application of the grease.

Lime-Base Greases. Long experience has proved that lime-soap greases are not suitable for general-purpose use in ball-bearing motors. Their melting points are too low especially for 40 to 55 deg C temperature rise rated equipment. Lime-soap greases separate badly after being in use a short while; greasing has to be frequent and as a result the motors become contaminated with oil. Most greases of this type contain from 2 to 5 per cent water which remains from the original larger amount incorporated during their manufacture. Once this water is lost by evaporation, constant shear, or by higher temperatures, the soaps and oils separate, leaving soap residues. This is detrimental to good lubrication, and bearing failure is a likely result.

It might be well to mention here that oil seepage is highly undesirable, not only from its possible destructive effect on windings, insulation, and commutators, but dirt easily adheres to it, gumming up operating parts.

It is possible to produce anhydrous calcium grease which does not have such a tendency to separate, but very little is generally known as to the value of this type of material.

Aluminum-Base Greases. Most aluminum-base greases are almost transparent and are commonly called solidified oils. While they do not show the rapid separation rate of lime-base soaps, they can be classed very closely to them as undesirable. Their melting points are low and with elevated temperatures they become more and more viscous or stringy. This increases fluid-friction rates, and the grease finally becomes either rubbery or is converted to a chalklike mass

Soda- or Soda-Lime-Base Greases. Practically all specifications covering general-purpose ball-bearing greases call either for soda- or soda-lime-base material; these include the specifications as outlined by all ball-bearing manufacturers. However, just because they are that type is not the answer. We all know there are inefficient as well as high-grade greases in these classes.

Long-fiber or sponge greases are not desirable. Most of them show too much separation in service. They stick to and ride the retainers of the bearings, aggravating by centrifugal force this tendency toward faster separation. Solids or near solids rapidly form, gradually choking ball or roller action. Electric-motor lubrication presents a far different problem than the front wheels of an automobile.

Greases for antifriction bearings should not be stringy or tacky; these types develop undesirable friction within themselves. They should either be smooth in texture or very slightly fibrous.

A highly important characteristic is that the grease should have a slight tendency to separate so that the races and balls are a little "wet" and not dry in appearance. This is true

Contributed by the Petroleum Division of The American Society of Mechanical Engineers.

lubrication. The exact extent of desirable separation is controversial but bearing failures leave little room for doubt that extremes in either direction are detrimental.

If the grease pack remains "dry" and a space finally develops between the grease pack and the bearing, a time arrives when the bearing itself needs more lubrication. In this case the only way the grease will move is by a temperature rise. All greases of this type have high melting points, and a temperature rise too great for the safety of the bearing would have to occur in order to move any grease into the bearing.

Lithium Greases. While lithium-base greases have high melting points, higher than most soda soaps, this feature cannot be used as a yardstick in measuring their ability to operate successfully in high temperatures combined with high speeds. In fact, research data at this writing is so inconsistent it would seem that much further investigation should be accomplished to classify this type of material properly. It is for this reason that careful consideration be given to operating conditions before a lithium-base grease is selected.

It is recognized that greases of this type have proved highly successful for operation in extremely low temperature or where water or moisture resistance is a desirable feature.

Inverted-Soda-Soap Greases. Inverted-soda-soap greases in general have the same characteristics as ordinary soda-soap greases and in addition they have higher melting points. They are water- and moisture-resistant if no more than a temperature of 120 F is reached. The principal disadvantages of this type of grease are the extremely low separation rate even under elevated temperatures and the tendency to harden under high speeds.

As a result of these conditions, this type of grease does not operate well at elevated temperatures and speeds and makes their usefulness in this field questionable.

Recent research, even though inconsistent, has shown that this type of grease warrants further development.

METHODS OF EVALUATING GREASES

Up to the present time no standard test procedure has been formulated for evaluating greases, with the exception of the approved A.S.T.M. physical tests for soap base and percentage, oil viscosity, penetrations, acid-alkali determinations, contamination, fillers, and moisture.

It must be admitted that even today grease making is not yet an exact science, it is still to a large degree a grease-makers' art which cannot be written into a physical test. It is for this reason that physical tests must be considered only primary. An unknown number of greases can meet the usual specifications laid down, including some government requirements, but too few perform satisfactorily.

Much effort has been made in the past few years to develop performance-test equipment, but as yet none of these machines has been accorded universal approval. Each machine is developed more or less to cover the requirements of the particular equipment of a given concern and is of little value when applied to other equipment.

The Annular Bearing Engineers' Committee has set up some standards of its own using the oxygen bomb and the A.B.E.C. testing machine.

The oxygen bomb has real value in that it can closely predict stability or storage life of grease in bearings. It has value in choosing lubricants for high-temperature application. It has little or no value in establishing operating characteristics.

The A.B.E.C. testing machine has the ability to eliminate unsatisfactory greases quickly, but the time element in making these tests is so short that its performance prediction for long service periods which are normally required in the field may fall short in accuracy. It does not give the better lubricants a chance to be graded properly. Even greases which have not performed so well in this test have shown very satisfactory service records in the field.

Much interest has been taken in the pressure viscometer and entirely satisfactory bleeding-test equipment has been built.

Cold-test equipment has been built which has shown real value.

It is difficult to incorporate even a few of the many variables which the many types of equipment offer and combine them in one testing machine. Building test equipment for the observation of reactions to one variable, another unit for something else and trying to put them together on paper does not work too well. Accelerated tests can prove very misleading.

An A.S.T.M. Committee is now being organized to work out this entire problem, and it is hoped that this committee will eventually produce equipment that can be used with more universally consistent results.

At the present time the best way to determine the performance of a lubricant for a given assignment is to put the test greases in units to be operated under natural conditions and give them a year's run in actual or simulated service, or for any length of time, short or long, for which satisfactory service should be shown. It is well not to make decisions too rapidly. If a decision must be made without delay there is nothing to be done but be guided by the limits of experience.

Consistency of General-Purpose Grease. There are varied opinions on this subject, but experience indicates that a range of from 250 to 300 A.S.T.M. worked penetration generally operates very well. If the grease is much softer it might churn and pump out along the shaft as well as cause higher than necessary operating temperatures. If it is much stiffer continuous supply might be interrupted, and without more frequent lubrication bearing failure is likely to result.

Heavy greases also offer mechanical-handling difficulties.

Very little work has been accomplished on determining penetration values over wide temperature ranges, especially the correlation of curves obtained with actual performance. Recent investigation of greases submitted for high-temperature high-speed operation gave the following trends; there being an interesting correlation between these curves and lubrication characteristics:

Grease No. 1 in Fig. 1 shows high susceptibility to temperatures in all ranges and it was not considered as useful material.

Grease No. 2 has an interesting temperature-range curve, but the fact that it is so soft brought up the question of its ability to remain in the housing.

Grease No. 3 shows undesirable hardening characteristics after a temperature of 100 C is reached.

Grease No. 4 has a consistent curve that proved satisfactory in high-temperature tests combined with high speeds.

Grease No. 5 would appear to be too hard at any workable temperature.

New grease might churn for a short period until it finds its steady working position as a grease pack.

At normal operating temperatures, heavy greases are liable

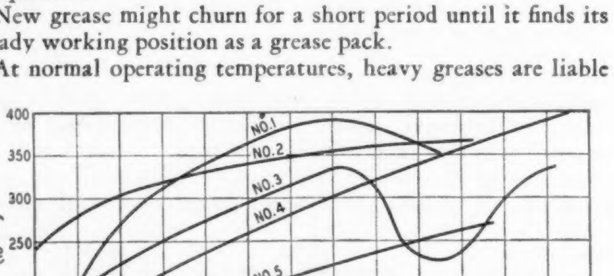


FIG. 1 CONSISTENCY VERSUS TEMPERATURE OF BEARING GREASES

to offer only borderline lubrication or provide a film so heavy that it will shear at points of rubbing contact. This is particularly true in all types of roller bearings.

Color of Grease. Color itself of course has nothing to do with the lubricating ability of the grease. It usually is controlled by the color of the oil used in its manufacture. Some greases are dyed for reasons of identification, trade purposes, or color uniformity, and in some instances to disguise a product of poor appearance.

It is not always easy to keep grease clean and since contamination is one of the things we fear, a light-colored grease is preferable to a dark product of equivalent value as contamination can be more easily seen and remedied.

Dark-colored greases do not lend themselves to a quick visual determination of condition changes which usually mark the progress of oxidation. If a definite system of cleaning bearings is not in effect, the color change of a grease serves as an indicator and old grease can be washed out and renewed at the proper time.

If the pressure-relief system is used for greasing, the difference in the color of the new grease and the old makes it easier to determine when the new grease is coming from the drain hole. It may be seen again that a light-colored grease is preferable to a dark grease of equivalent properties.

HOUSING DESIGN AND ITS RELATION TO GREASING

We constantly read and are told that an antifriction-bearing housing should contain no more than a one-third to a one-half filling of grease. It is true that this is an ideal quantity but this advice is not followed by a suggested method by which the amount can be maintained over a period of years with periodic greasing. Original fillings can be quantity-controlled, but from then on guesswork must be the rule. Quantitative applications have been successfully arranged for railroad traction-motor equipment to the point of "ounces" added twice a year. This has been accomplished after much study, and it works.

The general factory problem presents greater complications, keeping in mind that there may be several hundred or several thousand different sizes and makes of motors in use with several men applying the lubricants. This group constantly changes in personnel, and no quantitative greasing records are maintained.

The advice therefore to keep housings one third to one half full is highly idealistic, and its steady accomplishment practically impossible.

The over-all picture of motor design prompts the author to offer the suggestion that there is still much room for the study and development of better designed housings so that good accurate lubrication systems can be provided in the interests of everyone concerned. Progress in this direction will greatly help in lowering maintenance costs.

While streamlining has made machine tools and other equipment more pleasing to the eye, it has also many times made the application of lubricants to motors more difficult. Machine designers and plant engineers should give more consideration to the maintenance problem; the ease of approach to both sides of motors without undesirable structural interference, wherever possible.

At present there are several housing designs and recommended means of lubricating motors.

Some have no drain openings at all, some are equipped with offset openings. The best designs have drain openings at the bottom where they are easily accessible.

In the first group the only way to grease is to start off with a one-third filling, adding a small amount of grease every 6 months. It is impossible to clean these housings without disassembly.

In the second group it is possible to use the pressure-relief greasing system but it is not possible to clean without disassembly as a quantity of cleaning oil and solvent would remain in the housing.

The last group offers the best conditions for pressure-relief greasing systems and cleaning without disassembly. The arrangement provides time, labor, production, and bearing-abuse savings beyond any other design or mechanical arrangement in the interests of long bearing life.

The "pressure-relief" system of greasing is accomplished by running the motor at full speed, taking out the drain plug, and pumping in new grease until the new grease appears at the drain opening. In cases where overheating has been noted, it has been found that the plug was not left out long enough for the proper purging of any excess grease. Leaving the plug out for $^1/_2$ hr while the motor is running is usually sufficient.

Another excellent system, also the pressure-relief type, is where the grease enters the back side of the housing, goes through the bearing, and comes out at the drain opening at the bottom of the closure.

One large concern has an interesting system. Its motors operate 7 days a week 24 hours a day. Hundreds of them cannot be seen from one end of the year to the other. These motors are cleaned and the bearing housings packed one third full of grease once a year, with no grease added during that period. This system has proved satisfactory for several years.

Bearing housings with considerable grease capacity and with small drain holes provided, do not lend themselves to this system of pressure-relief greasing. While insufficient pressure is exerted or developed to force grease through the small drain hole, enough pressure can be built up to cause a fluid-friction temperature rise within the grease pack itself. Unless the excess grease can quickly purge itself through the shaft opening, a bearing failure might be encountered. The best way to service such a motor is to fill the housing manually about one third full at the start and add a small amount of grease every 6 months, never allowing the housing to become more than half full. It would not be amiss to attach a record tag to such motors with instructions on the quantity of grease to be added at each interval, the date of the application, and the initials of the man performing the work. The "guess" should be taken out of this problem as completely as possible.

There will almost always be a slight temperature rise noted immediately following the use of the pressure-relief system but it is of short duration and of no consequence. Higher-viscosity oils will sustain a temperature rise longer.

It is not necessary to grease motors operating under normal conditions oftener than once in 6 months.

MAINTENANCE AND OVERHAUL

It is generally conceded that laboratory conditions do not prevail on plant operating floors or in repair departments and that conditions under which maintenance men must work are often very difficult. These conditions must be met with added care, not with added carelessness.

Careless handling of bearings during overhaul and poor maintenance practice can cause no end of trouble. The Annular Bearing Engineers' Committee has treated this subject fully in a recent publication.[1] It is with this in mind that every effort is being made to give it wide distribution.

The maintenance of antifriction bearings is not necessarily a difficult problem provided lubricants are selected with care and the men applying them perform their duties with skill and interest. It is the violation of ordinary good judgment which produces the most trouble. Difficulties need not reach epidemic proportions before the maintenance problem warrants increased attention. It is the ever-present monthly or yearly replacement record that will bear analysis. Some surveys show conditions that could be so much improved that one wonders what keeps the equipment in operating condition. Many plants,

[1] "Anti-Friction Bearing Maintenance," Publication AFBMA-100, Anti-Friction Bearing Manufacturers Association, Inc.

both large and small, could and should improve their methods, materials, and personnel for handling this important work. Bearing losses alone are not the only phase for consideration, since the effect of improper maintenance on other parts of the equipment must also be taken into account.

Overgreasing. The introduction of too much grease into an antifriction-bearing housing will always result in excessive temperatures which cause grease leakage which endangers electrical life of the motor, or causes bearing failures directly attributable to the elevated temperatures. Even though neither of the first two conditions results, the rate of oxidation is almost invariably increased which will necessarily decrease the life of the lubricant.

Undergreasing. Undergreasing consists of applying an insufficient quantity of lubricant or extending the period of relubrication over too long a time. In either case, this can only result in bearing failures.

Careless Handling of Bearings. Careless handling of bearings and introduction of foreign matter or dirt into them during overhaul impose a severe duty on the lubricant, cause undue wear and premature failure.

Incorrect Assembly Methods. Incorrect assembly methods during overhaul result in damage to the bearings, cause rough or poor operation in the motor or generator and shorten bearing life. Men involved in this work should be asked to study the Annular Bearing Engineers' Committee instructions.

PREVENTIVE MAINTENANCE

Cleaning and Flushing Materials. There are several high-grade cleaning and flushing materials under various trade names on the market today, prepared for this purpose. They are, in general, mineral spirits with sufficiently high flash points for safe use as a general-purpose solvent.

Kerosene and commercial carbon tetrachloride are likely to be contaminated and may do more harm than good. If not thoroughly washed out, carbon tetrachloride can hydrolize to hydrochloric acid with consequent severe corrosion.

Cleaning Without Disassembly. Many motors are now designed with drain plugs at the bottom of the end caps which permit cleaning without disassembly. If equipment is found without drain openings at this point and it is possible to drill the end caps so they can be used effectively, it would be well to perform this work at an opportune time so that this cleaning process can be used.

Remove the pressure nipple, loosen the drain plug, and with the use of a small funnel pour in the solvent until it begins to bubble at the top. Run the motor for about 2 min and drain. It might be necessary to loosen any hardened grease away from the drain hole to permit flow. Repeat this until the cleaning fluid comes out clear. Fill the housing with light oil, be sure to drain off the oil throughly, and apply grease.

The average bearing housing should be cleaned out at least every 3 years.

Disassembled Bearing Cleaning. Proper equipment should be provided for this work and should consist of at least two pails, each with a wide-mesh screen soldered about 3 or 4 in. from the bottom. The screen keeps the bearings from dropping to the bottom and sediment is not easily disturbed by cleaning-material turbulence. One pail will contain the solvent and the other, light oil.

For the most satisfactory results, a third pail should be added containing oil heated to about 180 F. This insures better protection against all contamination and moisture.

If the bearings are to be stored for a long time or held for spares it is best in addition to dip them in hot petrolatum or vaseline.

High-Temperature Operation. Development of greases for use in high temperatures over long periods has not been encouraging thus far. A high rate of oxidation develops after 180 to 190 F is reached. It should be kept in mind that the rate of oxidation doubles for every 15 deg F temperature rise. This is definitely noticeable beginning at 140 F.

Advertising has been noted that some particular grease "will never deteriorate" with the inference that it will take about anything you want to give it, and we also have noted publicity that particular greases can be used up to 300 F, with no mention of time limits.

These statements are apt to mislead and confuse designing engineers planning new equipment, or operating engineers when planning new installations.

High melting points have nothing to do with oxidation values and are not difficult to obtain. The oil used in the manufacture of greases is highly important as to its oxidation and evaporation values.

All greases will eventually deteriorate even under normal conditions, and we have yet to see any grease that will stand 300 F, or even anywhere near that temperature for any appreciable length of time, regardless of speed. Without even putting grease into a bearing, anyone can place the lubricant in a heat-controlled oven in glass dishes with no catalyst present at 250 F and observe the changes that take place. Weekly or even daily observations will show the increasing rate of destruction, the gradual change either to liquids or rubberlike substances. The rate of oxidation in this static test will be accelerated in actual operation.

In applying motors to equipment every effort should be made to keep the temperature variable as low as possible with the use of extended shafts, coupled drives, good ventilation, etc. As the heat variable rises, the oxidation-rate penalty increases.

If the correct grease consistency and housing design can be combined, the pressure-relief system can be used for maintenance regreasing, otherwise the housing should never be allowed to become more than half full. This can be accomplished by the initial application of a one-third filling, adding a small amount of grease every 3 months.

Housings should be cleaned out at least once a year.

Low-Temperature Operation. Several excellent greases have been developed for low-temperature operation in the lithium-soap-base class. These permit operation on even intermittent service at minus 60 to 70 F. It is claimed that some of these products will give satisfaction as low as minus 100 F.

In our northern plants using outdoor equipment or with motors installed in unheated buildings, it will be found that a good general-purpose ball-bearing grease with an oil viscosity of about 300 vis at 100 F, will be most satisfactory to minus 20 F.

Motors in Contaminated Atmospheres. If dust is the problem it will be very helpful to use a heavy unfilled sealing grease with a worked penetration of about 200 applied to the grease grooves so that only shaft clearance through the grease is permitted. This will bring the shaft clearance down from the usual 0.015 in. to about 0.003 in.

If much product dust is actually getting into the bearing housing it might not be safe to use solvent-type flushing oils for cleaning without disassembly. The dust might not be of a character that would stay suspended in the solvent and rapid precipitation might cause the contamination to pile up in a solid mass at the bottom of the bearing or housing and fail to move out through the drain opening. It would just be left for the new grease to pick up in such large solid groups that an early bearing failure might result.

This problem should be studied on the job itself. It might be possible successfully to use an S.A.E. 20 oil so that the dust will float in it long enough to come out with the cleaning oil. This heavier oil will not produce the usual cleaning effect of solvents but it might be very useful and helpful.

The safest method, provided the housings are adapted to it, would be to use nothing but the pressure-relief system of greasing. Experience will have to determine how often it will be necessary to disassemble the unit for proper cleaning.

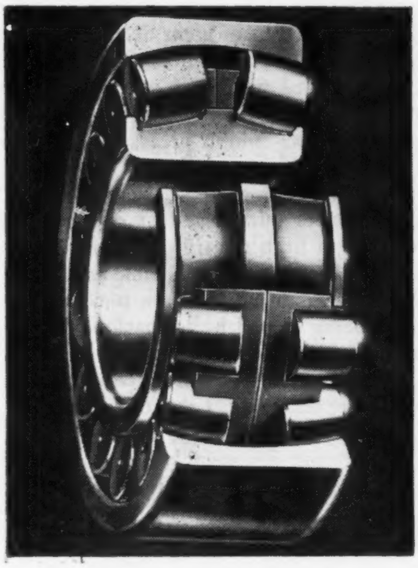


FIG 2 SPHERICAL ROLLER BEARING

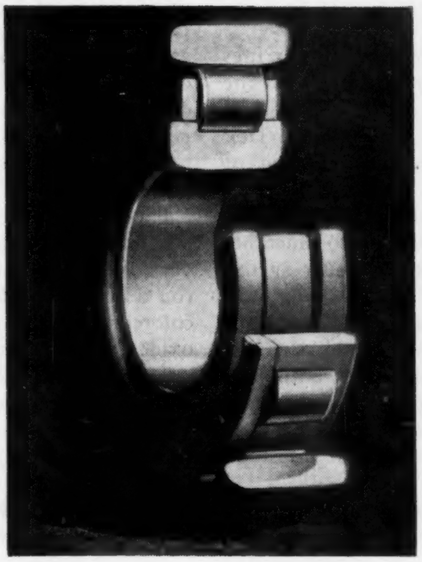


FIG. 3 CYLINDRICAL ROLLER BEARING

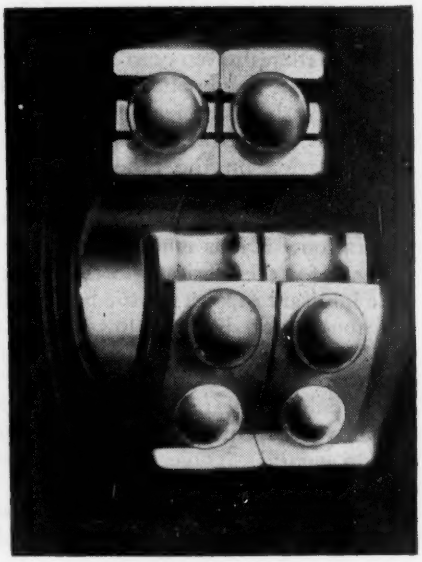


FIG. 4 DOUBLE-ANGULAR-CONTACT BALL-BEARING ASSEMBLY

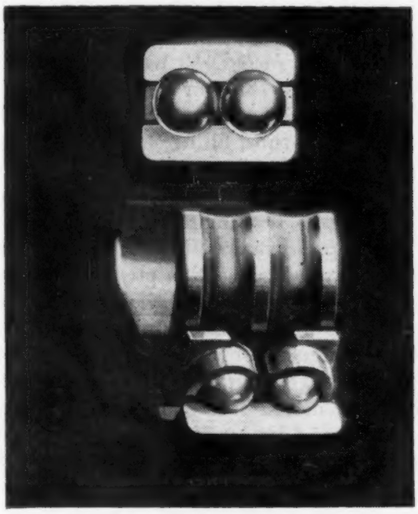


FIG 5 DOUBLE-ROW DEEP-GROOVE BALL BEARING WITH CAST-BRONZE RETAINERS

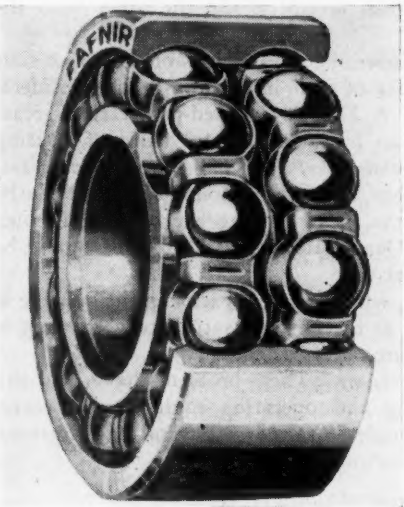


FIG. 6 DOUBLE-ROW DEEP-GROOVE BALL BEARING WITH PRESSED-STEEL RETAINERS

If destructive gases or vapors are present, such as sulphur dioxide or chlorine, it is best to try to use the pressure-relief system so that the housings are 85–90 per cent full all the time. Grease may have to be applied every month, or according to the percentage of atmospheric concentration or observed rate of destruction.

BEARING TYPES FOR SPECIAL CONSIDERATION

Heavy loads are always involved with the use of roller and double-row ball bearings. In addition, particularly in roller bearings, there is considerable rubbing and sliding contact which requires positive and "wet" films working on all surfaces. It is therefore obvious that greases on the softer side should be used, providing films heavy enough to carry the loads but thin enough so that film shear at points of rubbing contact will not occur. The grease pack should not churn.

Fig. 2 shows the SKF spherical roller bearing wherein it is essential that the inside ends of the rollers and the center-guide flange, as well as the cage pockets, be well lubricated. While oil is the preferred lubricant, grease is being successfully used.

Grease for this type of bearing should have a worked consistency of 300 to 320. All rollers should be grease-smeared during assembly and both sides of the bearing packed with grease up to the bottom of the inner race. A small amount of grease can be added every 6 months. Quantitative greasing records should be kept, attached to the equipment or available from files at date of greasing for the man doing the work. Three years of operation should not see this bearing housing much more than one third full.

Every 3 years, or according to severity of operating conditions, the bearings should be removed, thoroughly cleaned, and the initial operation of applying lubricant repeated.

Fig. 3 shows the cylindrical roller bearing where the two guide flanges as well as the roller pockets require lubrication. While the pressure-relief greasing system can be used with the proper housing design, it is best to proceed with the system outlined for spherical-bearing maintenance, using the same grease consistency, 300 to 320 worked penetration.

If drain plugs are installed at the bottom of the housing, these bearings can be cleaned, using the suggested method as outlined in this paper.

Fig. 4 illustrates a double-angular-contact ball-bearing assembly, one of the three mounting setups that are used, back to

back as shown, face to face or in tandem, according to the character of the load.

Many failures have occurred with double-row ball bearings because grease was applied to the outside row only, with the expectancy that sufficient grease would carry over to the inside row. Repeatedly, inspected failures have shown lack of lubrication on the inside row due to this method of greasing.

Grease for these bearings should be of at least 275–300 worked penetration; if it is much stiffer there will be considerable tendency for the lubricant to ride the retainers, offering too little lubricant support for the bearings.

If housings are built for low grease capacity and the drain plug is at the bottom, these bearings can be greased with the pressure-relief system, otherwise when mounting, both ball rows should be smeared with grease and both sides of the bearing filled one third full with a small amount of grease added every 6 months. Three years should not see these housings more than half full.

Proper cleaning of double-row ball bearings by the flushing method might be questionable; it would be better to remove the bearing housing. Thoroughly clean and repeat initial method of lubricant application every 3 years or according to severity of operating conditions.

Figs. 5 and 6 illustrate the double-row deep-groove ball bearing, one with cast-bronze retainers, and the other with the pressed-steel type.

There are a great number of these bearings of the larger sizes in the field, the majority of them in housings with considerable grease capacity. A 275–300 worked-penetration grease should be used with an initial filling one third of housing capacity, packed on both sides. The balls should be grease-smeared during assembly. A small amount of grease can be added once in 6 months, never letting the housing become more than half full. Quantitative greasing records should be kept for such equipment.

For the smaller sizes, where grease capacity in the housing is small with drain plug at the bottom, satisfactory greasing is possible with the pressure-relief system.

Rust and Corrosion Problems. These problems have held the interest of ball-bearing and operating engineers for years, and they offer many angles for study. Several basic reasons are offered for consideration:

1 Improper application of motor types.
2 Use of the wrong type or low-quality lubricant.
3 Improper cleaning of bearings.
4 Improper flushing of housings without disassembly.

Many surveys have shown that open-type ball-bearing motors have been used where splashproof or totally enclosed motors should have been installed. These have been found on roofs of buildings without proper housing protection, in food-processing plants where it is necessary to "hose down" every day, and in locations where heavy steam vapors exist. The operating locations cannot be changed but the application of motor types better suited to these conditions would offer considerable improvement.

The cheaper greases will almost invariably promote rust and corrosion owing to their original water content or rapidly developed organic acids.

A change from waterproof grease to water-soluble types would offer great improvement where rust or pitting is noted.

Waterproof greases isolate moisture so that it collects at the bottom of the bearing and housing or is interspersed in isolated globules through the grease. Every chance is thereby offered for clear water to reach the steel surface itself especially during periods of shutdown.

Soda or soda-lime greases absorb moisture-forming emulsions that provide protection against rust. If the absorption rate is severe, greasing periods might have to be shortened in order to correct any thinning of the lubricant. Here, again, the pressure-relief greasing system will be of great help and value, as any excessively softened grease can be eliminated through the drain opening. This is suggested procedure where moisture conditions are more or less constant. However, if water should get into a housing containing water-soluble greases under some temporary condition, all grease should be cleaned out and renewed.

Paper mills and textile plants offer excellent examples of production under conditions of high relative humidity. Surveys of conditions in these plants have shown, time and again, the telltale reddish-colored greases which were once amber-colored, the color change being caused by formations of iron oxide as a result of using waterproof grease.

Cleaning materials for disassembled bearings are sometimes left too long in buckets before renewal. Contaminated cleaning solvents or flushing oils are an invitation to rust.

In cleaning housings without disassembly, all traces of solvent should be removed with a light flushing oil. If left in the housings, many solvents can promote rust.

The use of compressed air is never recommended.

Vertical Motors. The same general practice outlined can be used for applying greases to the various designed housings, but in some cases it might be found best to use a grease with a worked consistency of 225 to 250. A change can be made from the general-purpose material if much leakage is noted, provided the reason is not improper greasing or overgreasing.

Slow-Speed Motors. It has been noted that slow speeds have a tendency to thin out a grease whereas high speeds stiffen it. If any thinning-out trouble is experienced, the housing, held to about a one-third filling, will help considerably. If the problem is particularly troublesome due to air emulsions, a 225 to 250 worked-penetration grease can be used effectively, never allowing the housing to become more than half full.

Aircraft Generators. Military aircraft during wartime conditions have placed a high premium on savings in weight in all accessory apparatus. With the advent of electrically operated and controlled aircraft equipment, motors and generators have been designed for high output with low weight. This in general means that the motors and generators must operate at high speeds and high temperatures. The introduction of high altitude and its low temperatures, and also the widely separated geographical locations in which this equipment has to operate, have imposed extremely severe conditions under which antifriction bearings and their lubricants must operate. A plane does not always fly in one position, and this makes necessary versatility in mounting the apparatus.

Much research must be performed in order to find the answers to all the problems existing even though lubrication research has done much to improve the operation of aircraft equipment. Progress made in the aircraft field will necessarily be reflected in the industrial applications of the future. Lubrication development for conditions as outlined is a "must" project of the present and future.

Grease-Quality Control. Pertinent to this entire problem is the necessity of getting uniform material from the lubricant manufacturer month after month. Experimental kettles might give us an interesting product but the production kettles many times spoil the picture. Regular production batches have been known to vary considerably. Therefore, while a lubricant manufacturer might produce an interesting grease, it becomes his problem to prove that he can manufacture the same superior material over a long steady period. It should and it does require a long time to build real confidence around a ball-bearing lubricant.

Handling Equipment and Storage. Management has the responsibility of providing the best possible handling equipment for all lubricants. Nothing will encourage the greasing and oiling personnel more. No matter what the initial cost, results

(*Continued on page 669*)

Evaluating Ball- and Roller-Bearing

GREASES *in* ELECTRIC MOTORS

By H. A. McCONVILLE

SCHENECTADY WORKS LABORATORY, GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

THE testing program to be described is proposed as a means of determining the suitability of a grease for ball- and roller-bearing applications. It involves a performance test on a motor in the laboratory under conditions comparable to those encountered in industry, selecting severe service conditions to accelerate the test. It has been said that many ordinary grades of grease will be satisfactory for about 95 per cent of the bearing applications. It is the other 5 per cent of bearings which operate under unfavorable conditions, such as extremely high speeds, high or low temperatures, etc., that give trouble. The selection of a grease that will give satisfactory lubrication over all ranges of conditions is the aim of most grease consumers. Such a grease is not obtainable, but some greases will have wider ranges than others, and extending their limits is a step toward the ideal sought for. It is hoped that this paper will stimulate interest so that a code for evaluating ball- and roller-bearing greases for electric motors may be developed.

LABORATORY TESTS

Laboratory tests for physical and chemical properties can be made which, to some extent, will weed out the least desirable types of greases. No standard method of rating greases is available, and no doubt there will be wide differences of opinion as to what are suitable characteristics. The methods described are used by the author and represent only one opinion, but are presented for record and discussion.

Before giving a new grease a trial run in a test motor, it is subjected to various tests in the laboratory. These standard tests include A.S.T.M. worked consistency (also a consistency test which is not actually on grease in the unworked condition but in the "as-received" state when packed in the test cup with the minimum amount of working), dropping point, soap base, acidity or alkalinity, oil separation or bleeding, and dirt or foreign matter. The significance attached to these tests may be of interest to the reader.

If the grease is to be applied to the bearings through a pressure fitting by a hand-operated pressure gun, its consistency, as received, must not be so stiff that there is trouble in forcing it through the gun. If it is too soft, it may become too thin in operation and leak out of the bearing. The dropping point will aid in identifying the soap base, which determines whether the grease will be good for high temperatures or not; it also is one of the properties which changes with deterioration of the grease. The soap base, in most cases, can be determined by means of flame tests. The measure of free acidity or alkalinity will be an indication of the stability of the grease in service, also its tendency to bleed oil. The presence of free oil in pools in a container of grease is considered undesirable. The grease must be free from dirt and foreign matter. Methods for making these tests will be found in the Appendix.

TEST CONDITIONS AND SETUP

Assuming that the grease has the necessary properties that have proved by past experience to be needed for operation under specific conditions, it is ready for a trial run in a test motor. The motor used in most of the author's tests is a 30-hp standard induction motor, 3600 rpm, having No. 312 ball bearings in either end. It has pressure grease fittings for the pressure-relief system. No load is applied during the tests as it is felt that loading will not influence the breakdown of the grease, although it may shorten the life of the bearings. Suitable thermocouples are installed to read the temperature of the outer race of the bearings.

A motor of this size and speed provides more than average severity of service, so that by increasing the ambient temperature above normal, a 500-hr test will be fairly comparable with a year or more of usual service. It is suggested that the test conditions for a particular service be selected in order that the required life under the test conditions will be about 10 per cent of the desired service life.

TEST PROCEDURE

The suggested test procedure is as follows:

1 Clean bearings and housings thoroughly, using a suitable solvent. Do not flush with oil, as the oil film left on the bearing surfaces would affect the test results.

2 Fill the bearings by hand two thirds full of grease.

3 Run the motor for 500 hr after the bearings have reached the desired temperature, blocking off air circulation if necessary. The bottom drain plug should be removed and left out for 30 min after the maximum temperature has been attained. This avoids overheating which would result from expansion of the grease under heat with a consequent increase in pressure.

EXAMINATION AT COMPLETION OF TEST

At the end of the 500-hr run, examine the grease in both ends of the motor. To be satisfactory, the following requirements must be met:

(*a*) Bearings shall not become unduly noisy.

(*b*) No noticeable wear on bearing surfaces.

(*c*) No gumming of grease.

(*d*) No free oil collecting in the bottom of the bearing housings.

(*e*) No grease leakage out of the housings.

(*f*) Grease removed substantially free from metal particles.

(*g*) Consistency of grease should not increase (harden) more than a specified per cent.

(*h*) Dropping point should not be lower than specified figure.

(*i*) Acid content of grease shall not increase over specified figure.

If the grease meets these requirements, it is then ready to be given a service-performance trial in the field in the particular apparatus for which it was intended. Field performance is the only final answer, as many conditions may arise in service which cannot be predicted or duplicated in a laboratory test. The foregoing procedure provides a means whereby the consumer can be reasonably sure that the grease will perform well in his apparatus before he sanctions its use for production equipment.

Contributed by the Production Engineering Division of The American Society of Mechanical Engineers.

SUGGESTED LIMITS

The purpose of this paper is to set forth a generally useful test procedure, and not to propose any test limits or standards. However, the test procedure will depend in some degree on the test limits. It therefore seems desirable to give some definite figures arrived at as a result of our experience. These are provided as a starting point for discussion.

It is felt that for ordinary motor applications the temperature a grease should stand on the high side is about 90 C (194 F), so the test temperature on the bearings is held at that figure. For higher-temperature applications or accelerated tests, it could be 100 C (212 F), or 110 C (230 F).

A motor speed of 3600 rpm is selected, as many greases will break down in a day's time or less at this speed where they may run for weeks or months at 1800 rpm in the same bearing. A 3600-rpm motor of the size mentioned (No. 312 bearings) is specified because we have found that grease which passes the test in this motor will be satisfactory over a large range of sizes and speeds of bearings. As a caution, however, tests made at 3600 rpm may not duplicate those at 5000 rpm or higher. A special test motor is needed for evaluation at these speeds.

It is realized that 500 hr may not be a long enough period, but many greases will change in a few day's time. It is not proposed to conduct the test to the destruction of the bearings as this makes the test too expensive and time-consuming.

Concerning the examination of the grease at the end of the 500-hr period, separation of oil does not exclude small drops of oil which may be scattered through the grease, but does bar greases which leave a pool of free oil in the bottom of the bearing cup. As regards change of consistency of grease in the bearing, the author's belief is that it should not get more than 15 points harder than the original unworked consistency at the beginning of the test. The free acid (calculated as oleic acid) should not be over 1 per cent.

DISCUSSION OF GREASES AND TEST METHODS

The fact must not be overlooked that sometimes samples of greases submitted for test are made in a laboratory on a small scale. These greases may give excellent results on the trial run. But, when the supplier makes them on a large scale in his grease plant, quite often he cannot duplicate his laboratory sample, due either to lack of ingredients which may be difficult to obtain or differences in manufacturing technique. Hence if it is known that the sample submitted is from a laboratory only, a thorough test should be made on the commercial product before assuming that the grease will be satisfactory.

A test setup, consisting of a number of bearings running on a shaft, which can be heated separately or collectively, is not advised, mainly because the grease acts differently in motor bearings. Its action in a bearing with a shaft passing through it will be different from that in one attached to a shaft on one end and fastened on with a nut enclosed by an end-bearing cap, as is customary on the end of the motor opposite the coupling end. Grease in this end of the motor will usually become much stiffer. The best check on changes of consistency of a grease is therefore made by testing the hardness of the grease in this bearing housing at the end of the test.

There are many differences of opinion as to how hard a grease can be and still successfully lubricate a bearing. This and many other questions can be settled more satisfactorily if a standard method of testing is developed.

SUMMARY

A test code for evaluating ball- and roller-bearing greases is proposed, involving a performance test in a ball-bearing motor. Preliminary examination of the grease is made in the laboratory, and some of the undesirable types of grease are eliminated. A standard test motor is described, also a procedure for conducting the test. Interpretation of appearance and physical and chemical changes in the grease at the end of the test run is offered. The proposed test is not the final answer, but is an intermediary step between laboratory physical and chemical tests and long-time life tests in apparatus in the field. It is not an attempt to cover the whole field, but is confined to ball bearings operating at speeds below 5000 rpm. Other tests may be proposed later if this type of test proves acceptable to industry.

Appendix

The recommended methods for laboratory measurements of grease properties are largely covered by A.S.T.M. Standards on Petroleum Products and Lubricants. They are listed in Table 1, for convenient reference, together with supplementary information.

TABLE 1 RECOMMENDED METHODS FOR MEASURING PROPERTIES OF GREASES

Worked consistency	A.S.T.M. method D217–38T
Unworked	A.S.T.M. method D217–38T
Dropping point	A.S.T.M. method D566–42
Free acid or alkali	A.S.T.M. method D128–40

The soap base will be indicated somewhat by the dropping point of the grease. A check can be made using a flame test. Details of this test have been published previously.[1]

If the dirt or foreign matter in grease is to be checked very carefully, the following procedure taken from Government specification AN-G-3a should be followed:

F-5g: Dirt. Dirt in the grease shall be determined on a sample of known volume, not less than 5 cu mm, which shall be prepared on a clean glass slide in a film approximately 0.15 mm thick, cleared of air bubbles by exposure to 29.30 in. of mercury vacuum for 15 min, and then protected from atmospheric dust by a clean cover glass. All particles in the sample of 0.001 in. or larger shall be counted under a magnification of at least 60 diam, using a microscope equipped with a calibrated eyepiece micrometer. The control dimensions for all particles shall be the largest dimension except for fibrous inclusions for which the fiber diameter shall be the control dimension. If the sample contains one or more particles larger than 0.005 in. as herein defined a second and third similar sample shall be prepared and examined in the same way. If one or more particles larger than 0.005 in. are discovered in either additional sample, material shall be rejected; but if no such particles appear in either additional sample, the material may be accepted.

TABLE 2 SUGGESTED PROPERTIES FOR BALL-BEARING GREASE FOR BEARINGS OPERATING AT SPEEDS BELOW 5000 RPM

Worked consistency	275–295
Unworked consistency	265–295
Dropping point	150 C (302 F) min
Free acid	0.1 per cent max
Free alkali	0.6 per cent max
Soap base	Sodium-calcium, sodium, or possibly lithium combinations
Corrosion	Grease must not corrode cooper alloys, iron, or steel.
Saybolt viscosity of oil at 38 C (100 F)	250–500 sec
Water content	0.3 per cent max

COMPARISON OF GREASES USING SUGGESTED METHOD OF TEST

A few examples are given to show what may be expected when this test method is followed. All of these greases meet all of the ordinary laboratory test requirements (Appendix) without difficulty.

Grease A. A ball-bearing grease of about 308 worked con-

(*Continued on page 679*)

[1] "Identification of Types of Unknown Greases," by H. A. McConville, *Mill and Factory*, vol. 35, 1944, pp. 122–125, 202, 204.

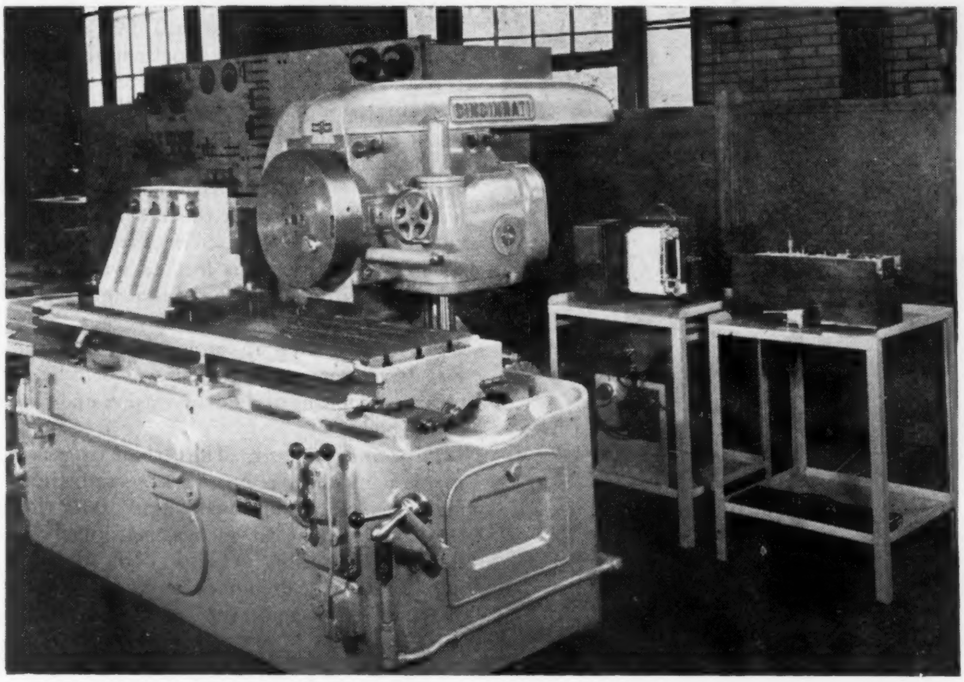


FIG. 1 CINCINNATI 5-60 HYDROMATIC MILLING MACHINE
(General view showing wattmeter and profilometer.)

MILLING CAST IRON *With* CARBIDES

By MICHAEL FIELD[1] and W. E. BULLOCK[2]

INTRODUCTION

THE advent of the war posed a difficult production problem in the milling of high-strength alloy steel in large quantities. At that time carbide milling of steel had been made possible by employing titanium- and tantalum-bearing tungsten carbides in combination with negative-rake-angle cutters. With this combination, phenomenal advances in the high-speed milling of steel were made, especially in the machining of gun parts at the Watervliet Arsenal (1)[3] and in the aircraft industry on the West Coast (2). Similar advances were instituted in the milling of aluminum for aircraft wing spars (3). It was therefore natural at that time also to consider the possibility of developing an improved technique for the milling of cast ferrous alloys, as these include the most commonly machined structural materials.

Cast iron and other cast ferrous alloys have been milled with carbide-tipped cutters in commercial practice for more than 10 years, the cutting speeds generally employed ranging from 150 to 300 fpm, with a feed per tooth from 0.003 to 0.008 in., and with rake angles ranging from zero to 10 deg positive. During the past few years an increasing percentage of all machining of ferrous castings has been done with carbide-tipped cutters.

In order to accelerate progress in this field (by investigating the possibilities of using certain new combinations of tool angles, cutting speed, etc., in the milling of cast iron) and to explore further the fundamental relationships involved in metal cutting, a research project of broad scope was instituted at the University of Cincinnati. Throughout the progress of this research, close co-operation was maintained between the University and the research department of the Cincinnati Milling Machine Company, so as to apply, wherever possible, the results of previous theoretical and experimental research (4, 5, 6, 7) and to provide a broad interchange of scientific knowledge, technical experience, and facilities.

A survey of previous work showed that, in spite of all the years of experience in milling cast iron with carbide cutters, there were few, if any, quantitative data available on the interrelationships of tool life, finish, and cost of milling with such factors as feed and speed, tool angles, depth and width of cut, and metallurgical structure. The primary object of the initial phase of the work at the University of Cincinnati therefore was to investigate the factors that basically determine the milling of cast iron and to obtain quantitative data on these relationships. It was felt that such a study would not only help the present war effort but would also improve future milling practice, especially in the automotive and machine-tool fields for milling cylinder blocks, machine beds, etc. The object of this paper is to present several of the important facts that have thus far been observed.

[1] Research Fellow, University of Cincinnati, Cincinnati, Ohio. Jun. A.S.M.E.

[2] Assistant Professor of Mechanical Engineering, University of Cincinnati, Cincinnati, Ohio.

[3] Numbers in parentheses refer to the Bibliography at the end of the paper.

Contributed by the Research Committees on Metal Cutting Data and Bibliography and on Cutting Fluids, and presented at the Chicago Section Meeting, Chicago, Ill., June 18–19, 1945, of The American Society of Mechanical Engineers.

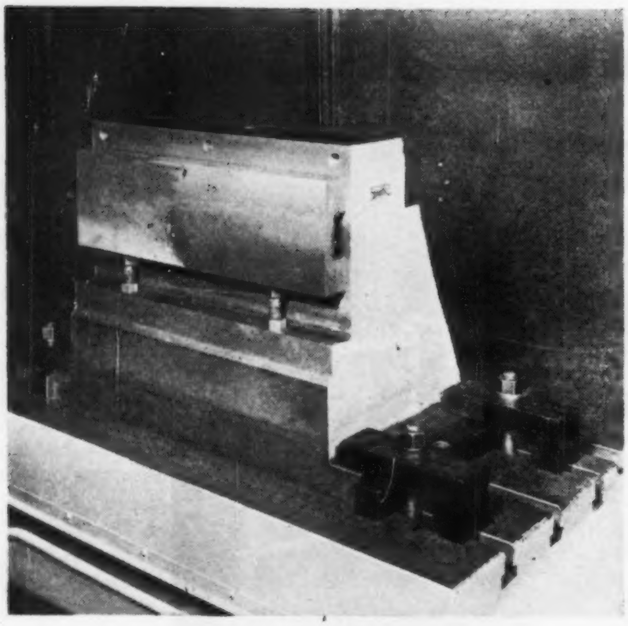


FIG. 2 WORK FIXTURE AND TEST BLOCK

It is hoped that this research and its findings will supplement rather than duplicate the excellent work now being carried on under W.P.B. sponsorship at the University of Michigan and the California Institute of Technology.

EQUIPMENT USED IN INVESTIGATION

The cutting tests were run on a Cincinnati 5-60 hydromatic milling machine, Fig. 1, having a speed range of 66 to 625 rpm. The table was hydraulically fed, with a feed range of 0 to 250 ipm. The machine was driven by a 25-hp induction motor, capable of being overloaded to about 60 hp, whose input was recorded by a General Electric recording wattmeter. The milling machine was calibrated by means of a prony brake at the spindle so that the relation between kilowatt input to the motor and the horsepower output at the spindle was known.

The test blocks were cast $6^1/_2 \times 3^1/_2 \times 20^1/_2$, and $^1/_4$ in. of the casting scale was first milled off all sides to avoid surface-casting variations. The blocks were bolted to a massive fixture and in addition were supported on two jack screws, Fig. 2.

A single-tooth cutter was held in a 500-lb flywheel, or body, 20 in. diam. This body was statically balanced and bolted to the spindle nose like a face mill, as shown in Fig. 3. Three tapered holes (No. 4 Morse taper) were provided in the body to accommodate the single-tooth cutter at a 4-in., 6-in., or 8-in. cutter radius. (In this series of tests only the 6-in. radius was used.) The cutter was located with respect to the body by means of a ground flat on the tool shank which was set radially to the cutter axis by means of a gage. The same ground flat was used in setting up for grinding the carbide tip. The cutter was driven into the body and was held by the Morse taper and secured by means of a heavy washer and screw against the rear of the body.

Preparation of Cutter. The carbide tip was brazed to the cutter shank using a low-temperature brazing alloy. A $7^1/_2$-kw Lepel induction-heating unit was employed for the brazing operation.

Grinding of the carbide was performed on a No. 2 Cincinnati cutter grinder using a $3^1/_2$-in-diam diamond cup wheel, having a $^1/_8$-in-wide diamond section on its face. The wheel was of 180-grit, 100-concentration, resinoid bond, and was operated

TABLE 1 CHEMICAL AND PHYSICAL PROPERTIES OF MATERIAL USED IN CUTTING TESTS

	"A"	"C-304"	"C-309"
Average Bhn	190	220	230
Tensile strength (1.2 in. arbitration bar), psi	50000	45000	40000
Total carbon, per cent	2.85–3.15	2.90–3.20	2.90–3.20
Silicon, per cent	1.20–1.50	2.45–3.00	1.60–1.85
Phosphorus, per cent	0.12 Max	0.18 Max	0.18 Max
Sulphur, per cent	0.20 Max	0.20 Max	0.20 Max
Manganese, per cent	0.8 –1,2	0.75–1.00	0.75–1.00
Chromium, per cent	...	1.00	1.25
Copper, per cent	...	...	3.00
Molybdenum, per cent	...	0.50	...

at 5300 fpm. Grinding was done wet, using water plus a rust inhibitor. In resharpening the carbide, all the effects of wear during the previous run were removed, plus an additional 0.010 in. from both the tool face and clearance lands.

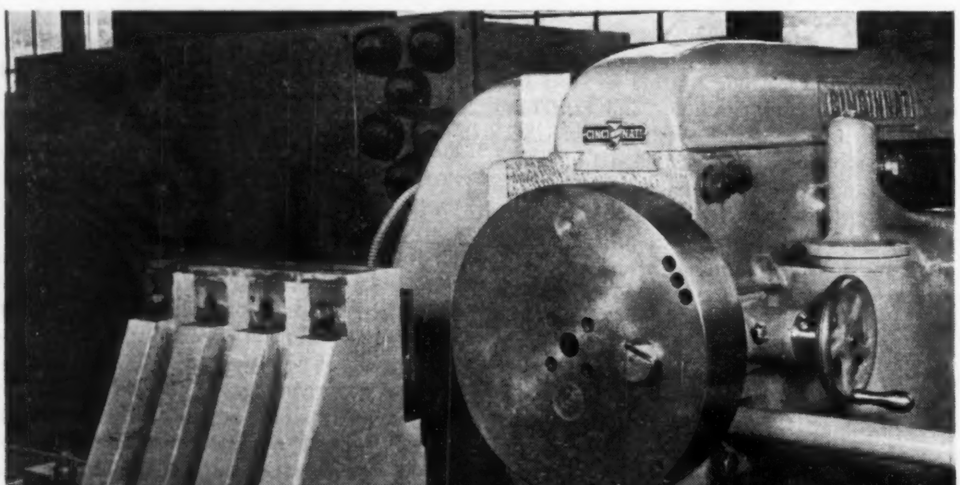
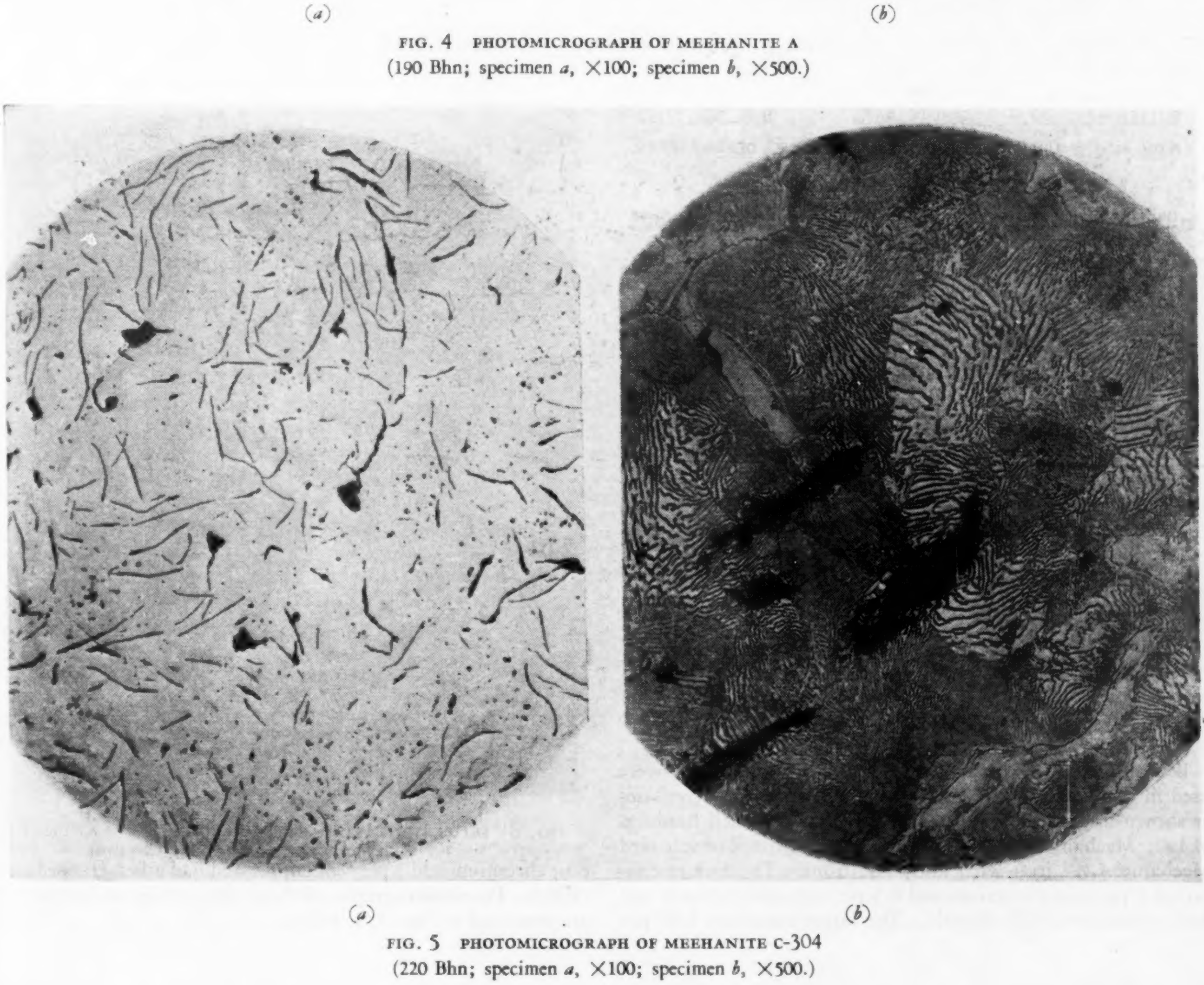


FIG. 3 CLOSE-UP OF HYDROMATIC MILLING MACHINE, SHOWING 20-IN-DIAM FLYWHEEL

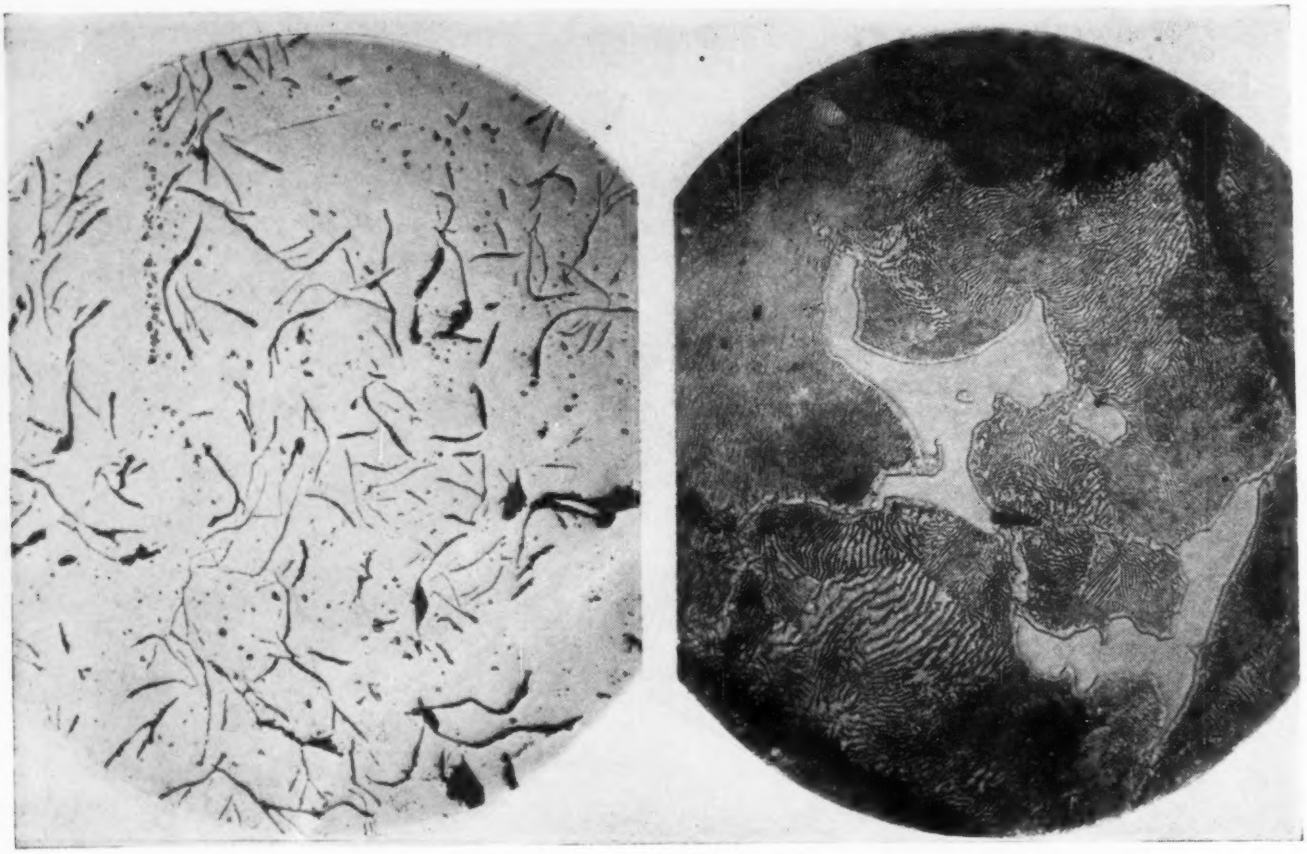
(a) (b)

FIG. 4 PHOTOMICROGRAPH OF MEEHANITE A
(190 Bhn; specimen *a*, ×100; specimen *b*, ×500.)



(a) (b)

FIG. 5 PHOTOMICROGRAPH OF MEEHANITE C-304
(220 Bhn; specimen *a*, ×100; specimen *b*, ×500.)



(a) (b)

FIG. 6 PHOTOMICROGRAPH OF MEEHANITE C-309
(230 Bhn; specimen *a*, ×100; specimen *b*, ×500.)

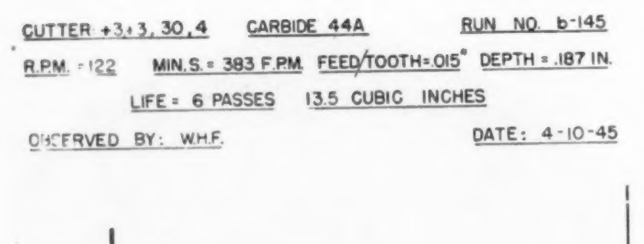


FIG. 7 TYPICAL TOOL-WEAR FORM

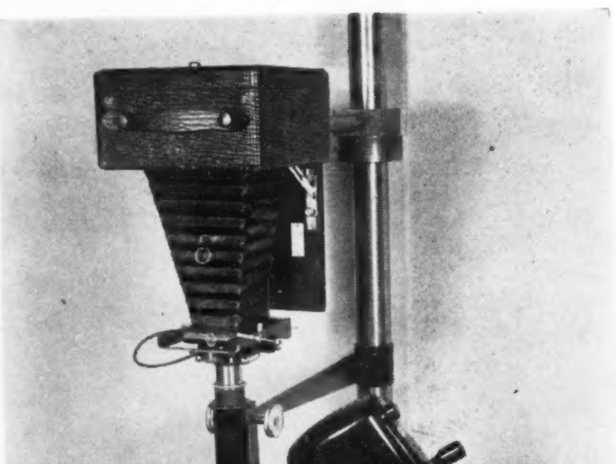


FIG. 8 SETUP FOR TAKING PHOTOMICROGRAPHS OF CUTTERS

Work Materials Tested. Three grades of Meehanite were used in these tests, with physical and chemical characteristics as shown in Table 1. Meehanite "A" had a Brinell hardness of 190; Meehanite "C-304" and "C-309" consisted of standard Meehanite "C" iron with alloy additions. The former contained 1 per cent chromium and 0.5 per cent molybdenum and had a hardness of 220 Brinell. The latter contained 1.25 per cent chromium and 3 per cent copper and had a Brinell hardness of 230. Photomicrographs of these three grades of Meehanite are presented in Figs. 4, 5, and 6.

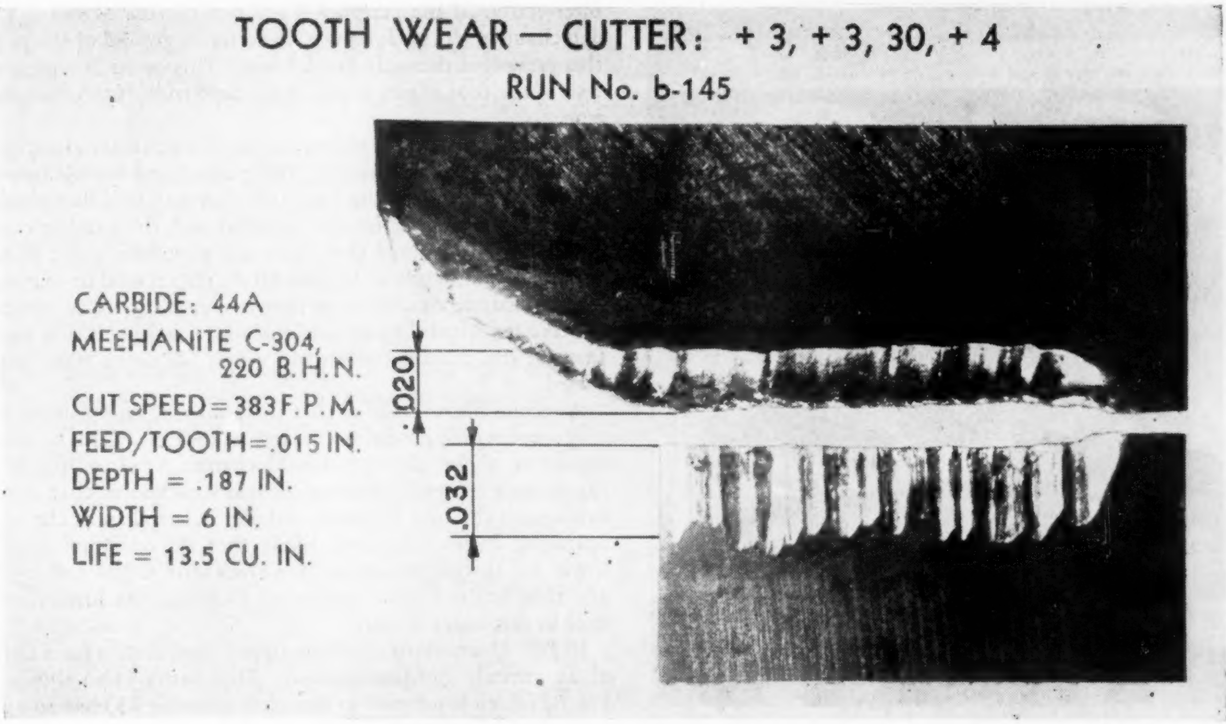


FIG. 9 TOOL-WEAR PHOTOMICROGRAPH CORRESPONDING TO WEAR FORM OF FIG. 7
(Enlarged ×15.)

TESTING PROCEDURE

In the entire series of cutting tests reported in this paper, the width of cut was 6 in. and the depth 0.187 in. This depth of cut corresponds to the average stock removal on automotive cylinder blocks and other medium-sized castings. The cutter was positioned centrally with respect to the work. The feed rate was set before a cut and checked with a stop watch during a cut. The actual spindle revolutions per minute were obtained from the power-calibration curve. The power was recorded throughout the run.

After the first pass over the work, the surface finish was measured with a profilometer, and a record of the finish was made on a "Faxfilm" plastic strip. These replicas are kept as a lasting record of the finish. Photographs were made from the Faxfilms of representative runs and will be shown later. The width of wear on the clearance land of the cutter was examined with a Brinell microscope after each pass. The test was considered ended when the width of the wear land reached 0.030 in., provided no other localized damage had occurred previously. This "tool-life end point" corresponds to that used both at the University of Michigan and the California Institute of Technology in the carbide milling tests run under W.P.B. sponsorship.

The actual wear pattern over the entire carbide was measured with a 40-power microscope having a micrometer scale in the eyepiece. The pattern was recorded on a wear form, Fig. 7, and representative wear patterns were photographed through the same microscope, Fig. 8.

A typical photomicrograph, which corresponds to the case recorded on the wear form, mentioned, is shown in Fig. 9. The 0.030 wear land with the 7-deg clearance angle produces a 0.0036-in. recession of the cutting edge; in addition, a crater is formed by the chips riding over the tooth face. This crater width was generally $1^1/_2$ to $2^1/_2$ times the maximum chip thickness and was about 0.005 in. deep for the majority of the cuts tested.

Sample chips were retained from each run and were measured for cutting ratio and chip flow angle.

SCOPE OF INVESTIGATION COVERED IN PAPER

From a production standpoint, the most important subject in any metal-cutting investigation is tool life. Tool life can be judged by several criteria as follows:

1 Actual cutting time to dull one tooth.
2 Number of chips to dull one tooth.
3 Total length traveled by tooth.
4 Total volume of metal removed per tooth.
5 Cubic inches of metal removed per inch of cutting edge per tooth.

The most significant of these from the standpoint of practical operation is the volume of metal removed per tooth, as this gives the most direct indication of the number of parts that can be milled before the cutter has to be resharpened. However, all the other criteria can be computed from the volume of metal removed as shown in the Appendix.

To study the factors that affect the tool life, two widely different cutters and three types of materials were chosen initially. The cutting speed was varied over a range of 200 to 1575 fpm, and the feed per tooth over a range of 0.005 to 0.065

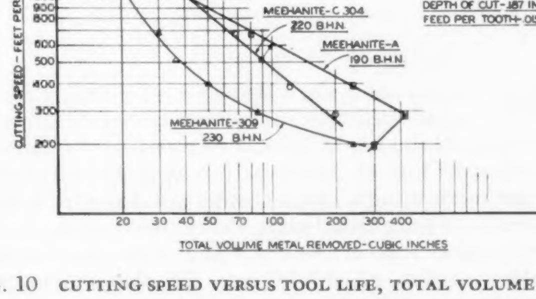


FIG. 10 CUTTING SPEED VERSUS TOOL LIFE, TOTAL VOLUME METAL REMOVED—COMPARISONS OF WORK MATERIALS
(Cutter: +3, +3, 30, +4.)

FIG. 11 CUTTERS HAVING $+15°$ AXIAL RAKE, $-30°$ RADIAL RAKE, $75°$ CORNER ANGLE, $+6°$ TRUE OR RESULTANT RAKE, AND $+32°$ ANGLE OF INCLINATION

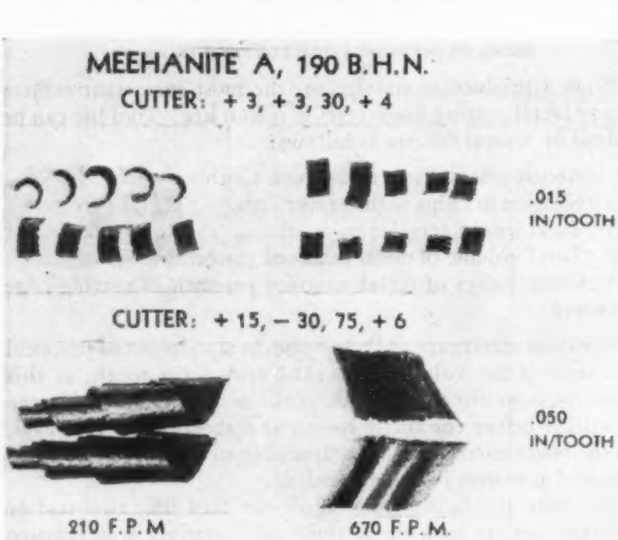


FIG. 12 REPRESENTATIVE CHIPS FROM $+3$, $+3$, 30, $+4$ AND $+15$, -30, 75, $+6$ CUTTERS; MEEHANITE A

(Width cut = 6 in.; depth cut = 0.187 in.)

in. In addition to the tool life, the surface finish, work breakout, and power were measured.

DISCUSSION OF RESULTS

Tool Life. In examining the relation between cutting speed and tool life, measured in terms of volume of metal removed, it is noticed that the life in general increases as the cutting speed is reduced. Fig. 10 shows the results obtained at 0.015 in. feed per tooth using a cutter (designated R6) with a +3-deg axial rake, +3-deg radial rake, 30-deg corner angle, and a resultant (or true) rake of +4 deg. This angle specification may be abbreviated to +3, +3, 30, +4. The clearance ground on all the edges was 7 deg. In the early tests it was found that this cutter broke down prematurely at the tooth point (the intersection of the peripheral and face cutting edges). A 60-deg chamfer $^{1}/_{16}$ in. long was henceforth ground at the point; this prevented the early breakdown. This cutter is representative of the tool angles in use in the field today for milling cast iron.

From Fig. 10, it is evident that there is a characteristic curve for each type of Meehanite. These curves are not all straight lines when plotted on log-log paper, but may be either straight or curved depending on the material and the cutting condition. It will be noted that there is a wide divergence in tool life at 300 fpm, while at 200 fpm all the curves tend to converge. The immediate conclusion is that it is not correct to compare relative machinability of cast irons at a single cutting speed. Instead, the characteristic speed versus life curve must be obtained.

A second observation is that there may be an optimum cutting speed which produces a maximum tool life. This optimum occurs at about 300 fpm for Meehanite A. It is logical to expect such an optimum speed for it is well known that at very low speeds the tool life with carbides is less than at the usual operating speeds. It seems likely that the optimum speed is lower for the harder materials (Meehanite C-304 and C-309) and thus has not been reached at 210 fpm, the lowest speed used in this series of tests.

In Fig. 11 are shown carbide-tipped tool shanks for a cutter of an entirely different design. This cutter (also shown in Fig. 3, which is referred to hereafter as cutter R8) has an axial rake of +15 deg, a radial rake of −30 deg, a 75-deg corner angle,

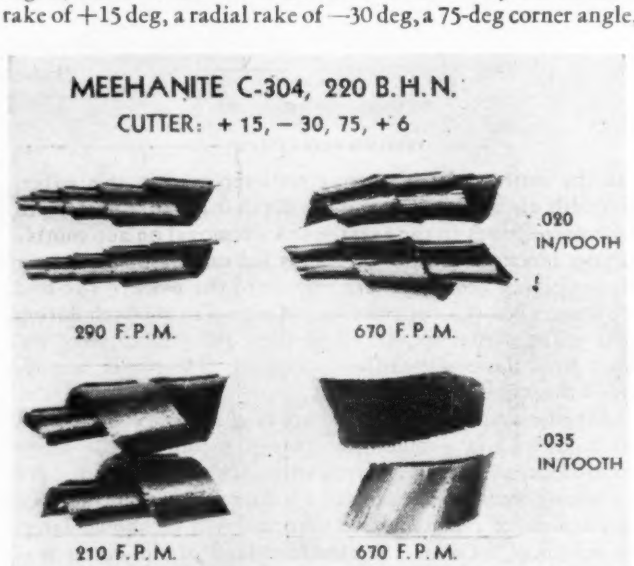


FIG. 13 REPRESENTATIVE CHIPS FROM $+15$, -30, 75, $+6$ CUTTER; MEEHANITE C-304

(Width cut = 6 in., depth cut = 0.187 in.)

a resultant or true rake of +6 deg, and an angle of inclination of +32 deg. (The "angle of inclination" is the angle between the cutting edge and a plane normal to the path of motion.) The large corner angle makes it possible to take a high feed per tooth without a correspondingly heavy chip thickness. In addition, the large positive angle of inclination usually provides a gradual engagement of the cutting edge as the tooth enters the work; it also results in a helically curled chip which freely clears the cutter body (8). Representative chips from cutter R6 and cutter R8 are shown in Figs. 12 and 13. It will be noted that the radius of chip curl increases with both feed per tooth and cutting speed.

The tool life obtained with this cutter in milling Meehanite A and Meehanite C-304 at 0.050 in. feed per tooth is shown in Fig. 14. The 0.050 in. feed per tooth resulted in a maximum "undeformed chip thickness" of 0.013 in., which is the same as that obtained with the 30-deg-corner-angle cutter

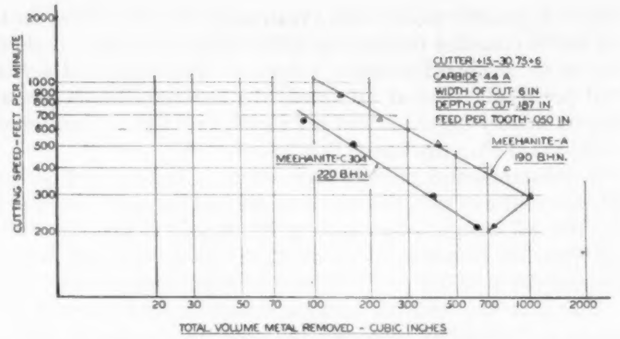


FIG. 14 CUTTING SPEED VERSUS TOOL LIFE, TOTAL VOLUME METAL REMOVED—COMPARISON OF WORK MATERIALS (Cutter +15, —30, 75, +6.)

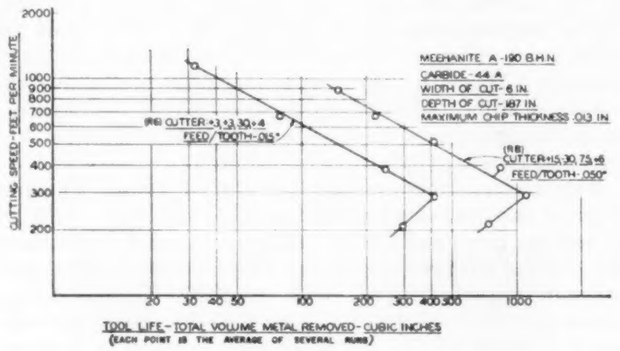


FIG. 15 CUTTING SPEED VERSUS TOOL LIFE, TOTAL VOLUME METAL REMOVED—COMPARISON OF CUTTERS +3, +3, 30, +4, AND +15, —30, 75, +6

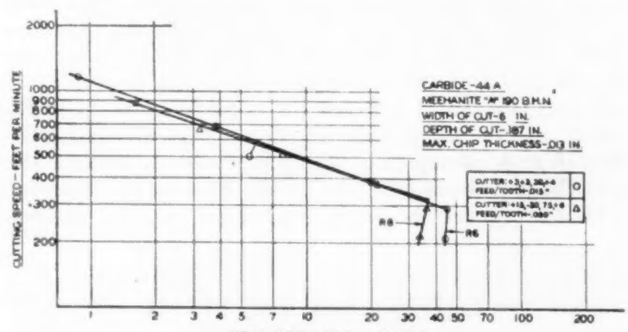


FIG. 16 CUTTING SPEED VERSUS TOOL LIFE, ACTUAL CUTTING TIME TO DULL TOOTH—COMPARISON OF CUTTERS +3, +3, 30, +4, AND +15, —30, 75, +6

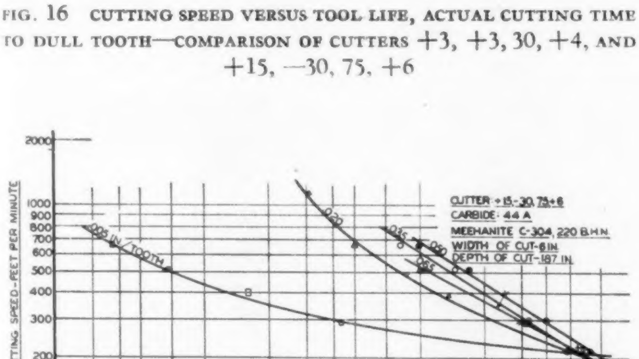


FIG. 17 CUTTING SPEED VERSUS TOOL LIFE, TOTAL VOLUME METAL REMOVED—AT CONSTANT FEEDS PER TOOTH OF 0.005 IN., 0.020 IN., 0.035 IN., 0.050 IN., AND 0.065 IN.

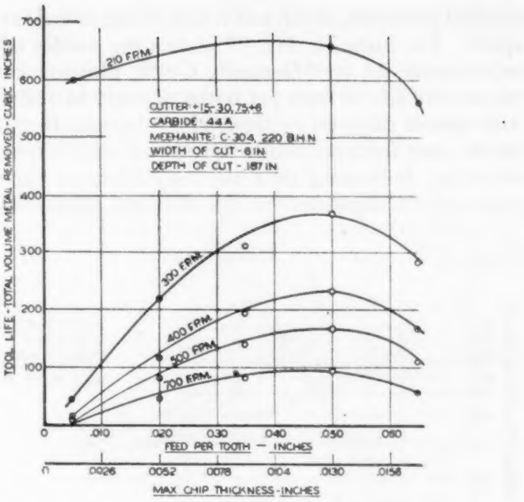


FIG. 18 TOOL LIFE, TOTAL VOLUME METAL REMOVED VERSUS FEED PER TOOTH AND MAXIMUM UNDEFORMED CHIP THICKNESS, AT CONSTANT CUTTING SPEEDS (Cutter +15, —30, 75, +6.)

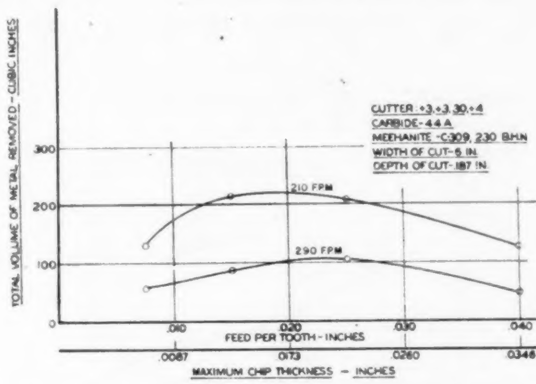


FIG. 19 TOOL LIFE, TOTAL VOLUME METAL REMOVED VERSUS FEED PER TOOTH AND MAXIMUM UNDEFORMED CHIP THICKNESS AT CONSTANT CUTTING SPEEDS (Cutter +3, +3, 30, +4.)

at a feed per tooth of 0.015 in. In other words, the 75-deg-corner-angle cutter can be fed at 0.050/0.015 = 3.33 times as fast as the 30-deg corner-angle cutter for the same undeformed chip thickness. In Fig. 14, it is seen again that Meehanite A could be milled with a longer tool life than Meehanite C-304.

The speed versus life curves for Meehanite A for the two cutters, R6 and R8, are shown in Fig. 15. The superior tool life obtained with cutter R8 is evident. The life for this cutter was $2^1/_2$ to 3 times that for cutter R6; in addition, cutter R8 was feeding $3^1/_3$ times as fast. An interesting fact is that the maximum tool life occurred at the same cutting speed for both cutters.

If the relation of cutting speed versus actual time to dull the tooth is compared for both cutters when milling Meehanite A, a misleading impression of tool life may be obtained, as the actual cutting-time curves are almost alike (see Fig. 16). The equal time values are due, of course, to the fact that while cutter R8 removed about three times as much metal as cutter R6, before dulling, it was fed three times as fast. One must be careful not to gain the erroneous impression from this type of plotting that both cutters performed equally well, as in reality cutter R8 would produce three times as many parts before dulling as cutter R6.

For a more thorough understanding of the performance of a given milling cutter, it is necessary to take into consideration

the feed per tooth, depth and width of cut, as well as the cutting speed. For instance, Fig. 17 shows the results of tests made with cutter R8 on Meehanite C-304, plotting cutting speed versus tool life at feeds per tooth of 0.005 to 0.065 in. At the high speeds there was a tremendous decrease in metal removal for the low feeds per tooth. However, at 200 fpm, the curves converge, indicating that the cutter life at this speed was practically independent of the feed per tooth. We thus see

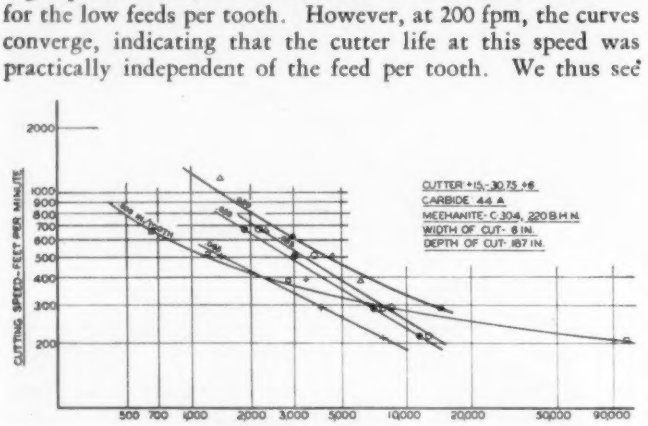


FIG. 20 CUTTING SPEED VERSUS NUMBER OF CHIPS TO DULL TOOTH AT CONSTANT FEEDS PER TOOTH OF 0.005 IN., 0.020 IN., 0.035 IN., 0.050 IN., AND 0.065 IN.

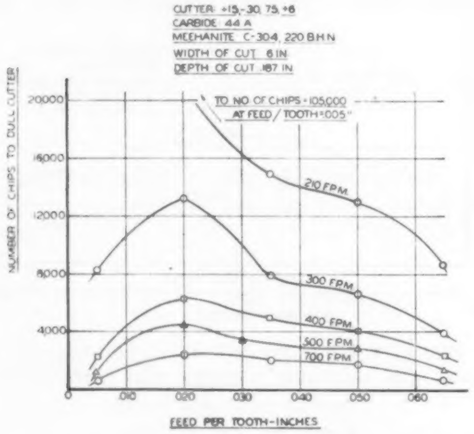


FIG. 21 NUMBER OF CHIPS TO DULL TOOTH VERSUS FEED PER TOOTH AT CONSTANT CUTTING SPEEDS

that it is possible to cut with a reasonable tool life at low feeds per tooth provided the cutting speed is likewise low. If these curves are replotted to show volume of metal removed versus feed per tooth, then at all speeds the optimum life occurs at approximately 0.050 in. feed per tooth, or 0.013 in. maximum undeformed chip thickness, Fig. 18.

A substantiation of this same trend is shown in Fig. 19, where volume of metal removed versus feed per tooth is plotted for the R6 cutter, when milling Meehanite C-309. Here the optimum life occurs at 0.017 to 0.025 in. feed per tooth, which corresponds to 0.013 to 0.022 in. maximum chip thickness.

If any of the tool-life criteria which depend on feed per tooth are employed to depict the tool life of the R8 cutter, when milling Meehanite C-304, again a misleading impression may be obtained unless a careful study is made. For example, if cutting speed is plotted against number of chips to dull the cutter, Fig. 20, the entire picture of relative tool life for the various feeds per tooth changes. Instead of all the curves bunching together at 200 fpm, the 0.020-in. feed per tooth curve indicates a far greater number of chips (or tooth impacts). This is brought out in Fig. 21, which shows the number of chips to dull plotted against feed per tooth at constant cutting speeds. The curves now peak at 0.020 in. feed per tooth instead of 0.050 in. feed per tooth.

If the actual cutting time had been plotted in place of number of chips, the same trend would have been observed. At 0.005 in. feed per tooth and 210 fpm, the actual time that the tooth was engaged with the work was 4.4 hr, whereas the total time to run the test with this one tooth was 30 hr. These high time values may give one the impression that the cutter performed better at 0.005 in. feed per tooth than at 0.050 in. feed per tooth, whereas with the latter feed somewhat more metal was removed in only 26 min actual cutting time.

Surface Finish. The surface finish obtainable was found to be a function of the type of cast iron, the cutting speed, and the length of the "face-cutting edge" of the tooth. The finish seemed to be independent of the type of tool and the feed per tooth, provided the length of the face-cutting edge was greater than the feed per tooth so that feed ridges could be avoided. A difference was noted between the appearance of the milled surface and the finish obtained with the profilometer. The Meehanite A castings had an open porous appearance that gave the impression of a poor finish, whereas the Meehanite C-304 castings for the same profilometer readings appeared

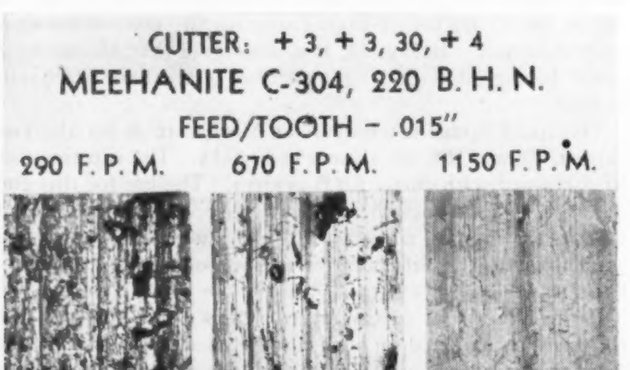


FIG. 22 QUALITY OF SURFACE FINISH OBTAINED WITH SINGLE-TOOTH CUTTERS

(Photographed from Faxfilm replicas using oblique lighting; magnifications ×20.)

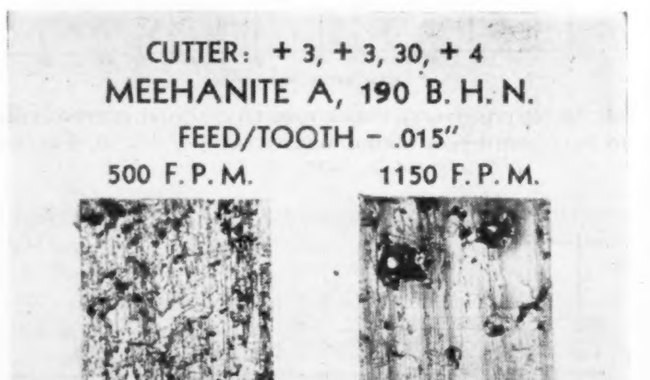


FIG. 23 QUALITY OF SURFACE FINISH OBTAINED WITH SINGLE-TOOTH CUTTERS

(Photographed from Faxfilm replicas using oblique lighting; magnifications ×20.)

less porous and therefore gave the impression of a better finish. (Compare the 190-microinch surfaces in Figs. 22 and 23.) The pitted appearance seemed to be related to the graphite-flake size, the larger graphite producing the more open finish. This has been mentioned in a paper by J. W. Bolton on the machinability of cast metals (9).

The surface finish, in general, improved as the speed was increased. Fig. 23 shows two surfaces milled with the R6 cutter at 0.015 in. feed per tooth, and Fig. 24 shows two surfaces milled with cutter R8 at 0.050 in. feed per tooth. Curves showing the average finish obtained at various speeds for cutters R6 and R8 are shown in Fig. 25.

In general, an improvement in finish was obtained as the cut progressed during any one run. The improvement was caused by the wear of the face-cutting edge so as to increase its length of engagement with the workpiece. A similar improvement in finish was obtained by using a long face-cutting edge to start with, e.g., about 3 or 4 times the feed per tooth. The only disadvantage of the long face-cutting edge is that it heats up rapidly, thus sometimes causing a chipping of the cutting edge.

Breakout. In milling brittle materials such as cast iron, a small portion of the workpiece breaks out at the edge where the cutter leaves the work. This breakout may be unimportant on some parts where this edge of the workpiece would subsequently be machined. On many other jobs, however, the breakout must necessarily be small. In this series of tests the magnitude of the breakout was found to be a function of the undeformed chip thickness but was practically independent of the cutting speed within the limits of the test.

The relative breakout for cutter R8 when milling Meehanite C-304 is shown in Fig. 26.

The ill effects of an undesirable breakout can sometimes

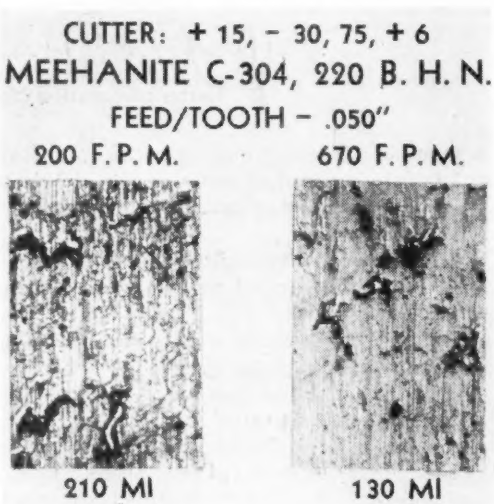


FIG. 24 QUALITY OF SURFACE FINISH OBTAINED WITH SINGLE-TOOTH CUTTERS

(Photographed from Faxfilm replicas using oblique lighting; magnifications ×20.)

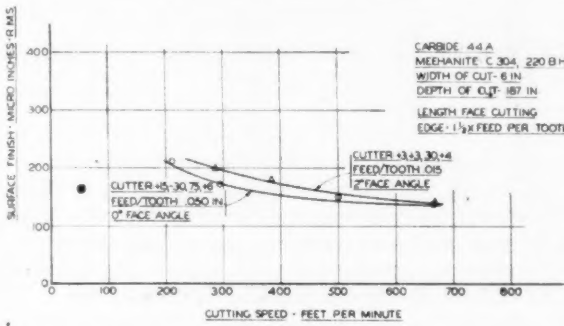


FIG. 25 SURFACE FINISH VERSUS CUTTING SPEED

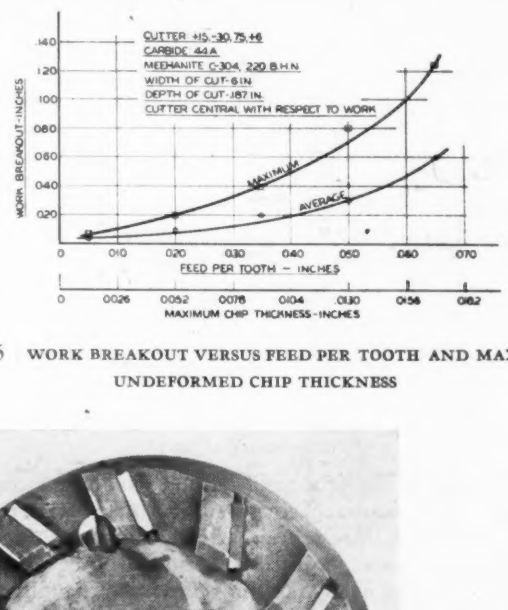


FIG. 26 WORK BREAKOUT VERSUS FEED PER TOOTH AND MAXIMUM UNDEFORMED CHIP THICKNESS

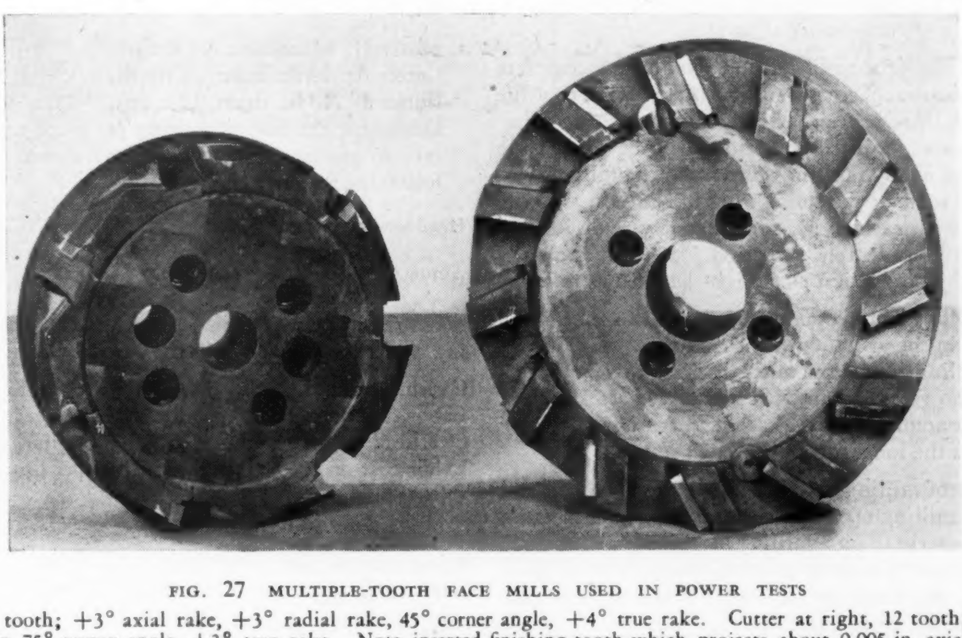


FIG. 27 MULTIPLE-TOOTH FACE MILLS USED IN POWER TESTS

(Cutter at left, 7 tooth; +3° axial rake, +3° radial rake, 45° corner angle, +4° true rake. Cutter at right, 12 tooth; +15° axial rake —30° radial rake, 75° corner angle, +3° true rake. Note inserted finishing tooth which projects about 0.005 in. axially beyond the 12 major teeth. This added tooth has a face-cutting edge 5/8 in. long which produces the finish on the workpiece.)

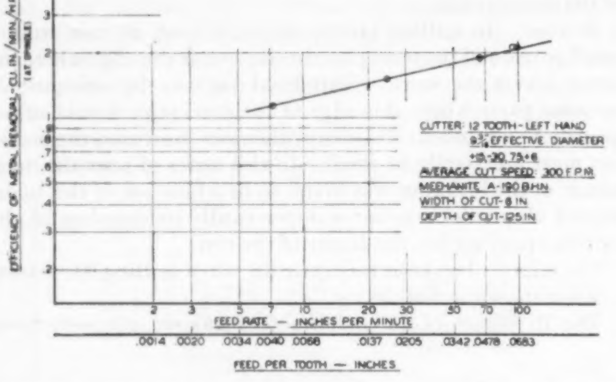


FIG. 28 EFFICIENCY OF METAL REMOVAL VERSUS FEED RATE AND FEED PER TOOTH

(Cutter +15, —30, 75, +6.)

be offset by casting a radius or bevel along the edge where the cutter leaves the workpiece. This practice has been followed on the cylinder bores of automobile engine blocks. Another method which may sometimes be employed to reduce the effect of breakout is to position the part so that the critical edge is on the side which is first engaged by the cutter.

Power Required for Milling Cast Iron. The power required for milling could not accurately be obtained in the single-tooth tests because of the variable tooth load. A series of power tests, however, were made with the multiple-tooth cutters shown in Fig. 27. The relation between the efficiency of metal removal (cubic inches per minute per horsepower at the cutter) versus feed rate and feed per tooth for the 12-tooth cutter M8 is shown in Fig. 28. In this test a cut $^1/_8$ in. deep and 6 in. wide was made on the Meehanite A test blocks at a speed of 300 fpm. Feeds up to 100 ipm were taken; this corresponds to a maximum feed per tooth of 0.068 in. The efficiency of metal removal increased with the feed, the equation represented by the curve being

$$E \cdot F^{-0.23} = 0.73$$

where

E = efficiency of metal removal, cu in. per hp per min at spindle

F = feed rate, ipm

COST OF MILLING

An analysis of the process of milling would be incomplete without the inclusion of cost relationships. The tool-life curves obtained in these tests are of prime importance in determining milling costs. So little attention has been paid in the past, even by large users of milling cutters, to the full story of milling costs, and so many misconceptions have arisen as to the savings possible with carbide milling, that it was decided to give this subject considerable attention. Several erroneous statements made by production men might be cited as follows:

1 Carbide milling is uneconomical because the time saved in milling is lost in the grinding of cutters.

2 Carbide milling is uneconomical because in many cases the cutter life is no greater than with high-speed steel cutters.

3 It is most economical to run a carbide cutter at the cutting speed which gives the longest tool life.

A cost analysis of milling should include the overhead and labor cost on the milling machine, cutter grinder, and brazing units. Since the overhead on a milling machine is about three times as great as that of a cutter grinder, then, for every hour saved in milling, one could spend 2 to 3 hours extra in cutter grinding and still "break even."

The choice of the best cutting speed and feed depends on many considerations; for example:

1 Is the cut roughing or finishing?

2 Is the aim to obtain maximum pieces per hour or to mill at the least cost per hour?

3 Is an automatic fixture or an indexing fixture available to reduce the loading and unloading time?

4 Is the work a small or large production job?

For the purpose of analysis, a simple example has been chosen which demonstrates the fact that it is impossible to jump at milling-cost conclusions, and that the only positive way of estimating the actual milling cost is to make a complete analysis.

The factors that determine the cost of milling may be combined into the following equation:

Total cost to mill one piece = C

$$C = \underbrace{\left[\left(M_{LO}\right)\left(T_m + \frac{T_o}{N_L} + \frac{T_r}{N_S}\right)\right]}_{\text{Milling cost}} + \underbrace{\left[C_u\right]}_{\text{Initial cost of cutter}}$$

$$+ \underbrace{\left[\left(G_{LO}\right)\left(\frac{T_S}{N_S} + \frac{T_B}{N_B}\right) + C_a + W\right]}_{\text{Cutter preparation cost}}$$

where

M_{LO} = labor + overhead on milling machine, dollars per min

G_{LO} = labor + overhead on cutter grinder, dollars per min

B_{LO} = labor + overhead on brazing unit (assumed = G_{LO}), dollars per min

T_m = total time to mill one piece, min
= feeding time + rapid traverse time + loading and unloading time

T_o = original setup time on milling machine, min

N_L = total number of pieces in lot

T_r = time to change and reset cutter, min

T_S = time to resharpen cutter, min

N_S = number of pieces milled per cutter sharpening

T_B = time to rebraze teeth (or reset blades), min

N_B = number pieces milled per brazing (or resetting)

C_u = original cutter cost per piece

C_a = carbide (or blade) cost per piece

W = wheel (diamond or abrasive) cost per sharpening

Example:

Operation: Mill surface 6 in. wide, 20 in. long, to a depth of $^3/_{16}$ in.

Material: Meehanite A 190 Bhn.

Cutter A: 10 in. diam, 12-tooth, +3, +3, 30, +4 (R6)

Cutter B: 10 in. diam, 12-tooth, +15, —30, 75, +6 (R8)

Determine the cost of milling per piece and the production rate in pieces per 60-min hr, with each cutter under the following four conditions:

Hand loading (time, 1 min)........................ { (1) 280 Fpm; (2) 500 Fpm }

Automatic loading (time, 0.2 min)................ { (3) 280 Fpm; (4) 500 Fpm }

For the purposes of this example, we may assume the following values for the factors in the cost equation:

Overhead on milling machine = \$4.00 per hr
Labor cost on milling machine = \$1.00 per hr
Overhead on cutter grinder = \$1.25 per hr
Labor cost on cutter grinder = \$1.00 per hr

Then M_{LO} = \$0.083 per min
G_{LO} = \$0.037 per min

Rapid traverse rate = 300 ipm

T_o = 60 min

N_L = 10,000 pieces in lot

T_r = 10 min

T_S = 120 min for cutter A

$$T_S = 240 \text{ min for cutter B (liberal assumption, to avoid any question of favoring this cutter)}$$

$$T_B = 60 \text{ min}$$

$$N_B = 4\,N_S$$

$$C_u = \frac{\text{Original cutter cost}}{\text{No. pieces milled with cutter}} = \frac{\$200}{50{,}000} = \$0.004$$

$$C_s = \frac{\$1.00 \times \text{No. teeth}}{3\,N_B} = \frac{\$12}{12N_S} = \frac{\$1.00}{N_S} \text{ for cutter A}$$

$$C_s = \frac{\$2.00 \times \text{No. teeth}}{3\,N_B} = \frac{\$2.00}{N_S} \text{ for cutter B}$$

$$W = \frac{\$.10 \times \text{No. teeth}}{N_S} = \frac{\$1.20}{N_S} \text{ for cutter A}$$

$$W = \frac{\$.20 \times \text{No. teeth}}{N_S} = \frac{\$2.40}{N_S} \text{ for cutter B}$$

Feed per tooth = 0.015 in. for cutter A
Feed per tooth = 0.050 in: for cutter B

The feed rate, T_m, and N_S will depend on the cutting speed for the respective cutters.

Cutter A. The tool-life values for each of the foregoing conditions were obtained from the curve of cutter R6 in Fig. 15. The tool life at 280 fpm was 430 cu in. metal removed per tooth, while at 500 fpm the life dropped to 150 cu in. By introducing appropriate values for the other factors in the cost equation, the cost per piece for each condition can be readily determined. The results are shown in the bar graph, Fig. 29.

Assuming the condition of 280 fpm, and hand loading as 100 per cent, we see that by increasing the speed to 500 fpm the cost per piece increased to 103 per cent but the production rose to 128 per cent.

By using automatic loading, but retaining the low speed, the cost decreased to 75 per cent, while the production rose to 141 per cent. Finally, by combining automatic loading and the high speed the cost fell to 78 per cent and the production increased to 204 per cent.

Cutter B. The tool-life values for the +15, —30, 75, +6 cutter was obtained from the curve of cutter R8 in Fig. 15. At 280 fpm, 1100 cu in. metal was removed per tooth, while at 500 fpm, the tool life dropped to 430 cu in. metal removed.

The production and cost per piece for this cutter are shown in Fig. 30. Again designating the condition of 280 fpm and hand loading with cutter A as 100 per cent, it is seen that cutter B, for the same speed and type of loading, gave a production of 167 per cent at 62 per cent of the cost. At 500 fpm and hand loading, the production was 184 per cent and the cost 73 per cent. With automatic loading and 280 fpm, the production rose to 324 per cent, while the cost dropped to 37 per cent. Finally, at 500 fpm and automatic loading, the production reached 399 per cent with a cost per piece of 47 per cent of that for the basic condition with cutter A.

From the foregoing analysis, it is therefore evident under the conditions of this example that the cutter having a combination of large negative radial rake (—30 deg), a corner angle of 75 deg, and a positive true rake of 6 deg, provides a large increase in production with a considerable decrease in cost per piece.

CONCLUSIONS

1 The results of the tool-life tests indicate clearly that the machinability of different cast irons can be compared only on the basis of their characteristic curves that relate tool life to cutting speed and feed per tooth, for a particular cutter. The relative tool life will be different if any of these factors is changed.

2 In a cutting speed versus tool life curve, there exists a maximum tool-life point toward the lower end of the speed range. This point probably occurs at lower speeds for the harder cast irons.

3 Relatively large differences in machinability exist with ferrous castings which do not differ greatly in Brinell hardness. The evidence thus far accumulated indicates that the machinability is related to metallurgical constituents which do not necessarily determine the average hardness.

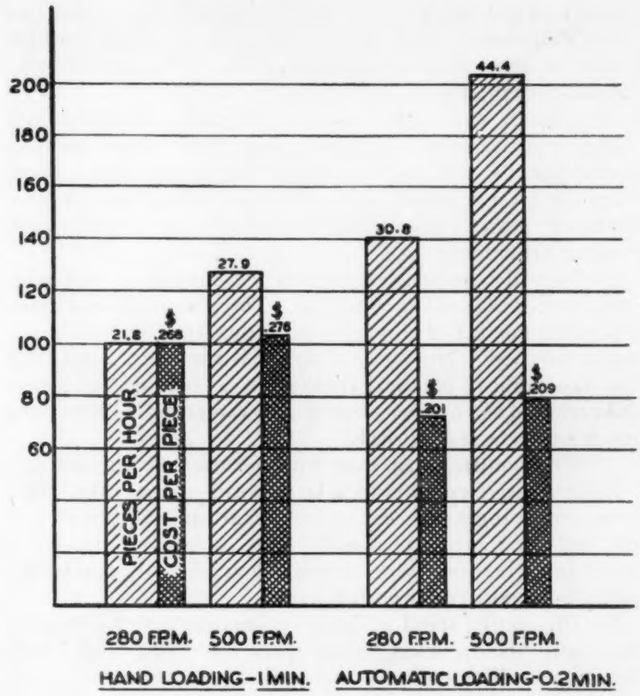


FIG. 29 COST ANALYSIS BASED ON MILLING MEEHANITE "A" BLOCK

(Cut, 6 × 20 × 3/16 deep; cutter 10 in. diam, 12 teeth, +3, +3, +30, +4.)

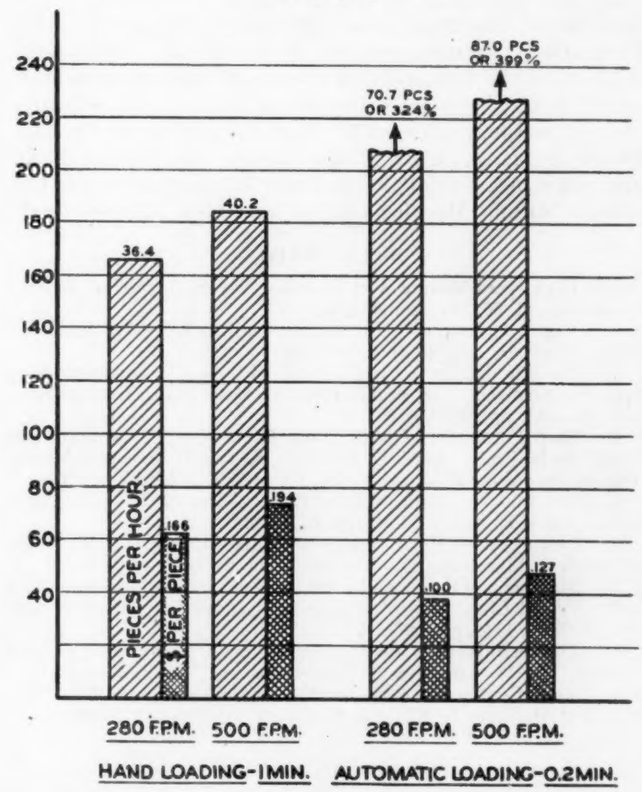


FIG. 30 COST ANALYSIS BASED UPON MILLING MEEHANITE "A" BLOCK

(Cut, 6 × 20 × 3/16 deep; cutter, 10 in. diam, 12 teeth, +15, —30 75, +6.)

4 There exists a maximum tool-life point in a tool life

versus feed per tooth curve. Curves obtained with different tooth shapes on a given cast iron have the maximum tool-life points at approximately the same value of maximum undeformed chip thickness.

5 A cutter which combines a large negative radial rake with a large positive axial rake, and a large corner angle (so as to give a positive true rake of about 6 deg) will remove a considerably greater volume of metal before dulling than the conventional positive-rake cutters which are in general use in commercial practice.

6 Tool-life comparisons for different conditions vary with the criterion selected for tool life. Three basic criteria exist; i.e., time, number of chips (or tooth impacts), and volume of metal removed. The latter criterion is the most useful from the standpoint of practical application, as it provides a direct indication of the number of parts that can be milled before the tooth has to be resharpened.

7 When milling cast iron with a cutter which combines a large negative radial rake, a large positive axial rake, and a large corner angle, the efficiency of metal removal increases, as the feed per tooth is increased. This confirms the results of other investigations with cutters where the rake angles are either both positive or both negative.

8 The cutting speed which gives maximum tool life is not necessarily the optimum cutting speed when all factors which determine milling cost are taken into consideration.

ACKNOWLEDGMENTS

The authors wish to thank the Cincinnati Milling Machine Company for assistance in carrying on this investigation. They also appreciate the aid of Messrs. D. R. Gebhart, Instructor in the Mechanical Engineering Department, Ray Fritz, Louis Patalita, and W. H. Friedlander, co-operative students of the University of Cincinnati, and other members of the faculty who have contributed to this work. Finally, the help and suggestions of Mr. Hans Ernst, Research Director, Dr. M. E. Merchant, Dr. M. Kronenberg, Mr. Norman Zlatin, and other members of the Research Department of the Cincinnati Milling Machine Co. are gratefully acknowledged.

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Appendix

DEFINITIONS AND EQUATIONS

w = width of cut, in.
d = depth of cut, in.
l = total length of cut, in.
F = feed rate, ipm
N = spindle speed, rpm
T = number of teeth in cutter
D = diameter of cutter, in.
S = cutting speed, fpm = $\pi DN/12$
V = total volume metal removed, cu in.
V = width cut × depth cut × total length cut
$V = w \times d \times l$

$$F_t = \text{feed per tooth, in.} = \frac{\text{Feed rate}}{\text{No. teeth} \times \text{rpm}} = \frac{F}{TN}$$

t_c = chip thickness of undeformed chip based on circular tooth path (in.)

$$t_c = F_t \cos c \sqrt{1 - \left(\frac{2e}{D}\right)^2}$$

c = corner angle, deg
e = distance, perpendicular to feed, from center of cutter to position on work where chip thickness is being considered, in.
l_a = length of arc of tooth path, in.
C_h = number of chips removed to dull one tooth

$$C_h = \frac{\text{Total length of cut}}{\text{No. teeth} \times \text{feed per tooth}} = \frac{l}{T \times F_t}$$

T_a = actual cutting time to dull one tooth, min

$$T_a = \frac{\text{Total length of cut}}{\text{Feed rate}} \times \frac{\text{Length of arc}}{\text{Circumference of cutter}} \times \frac{1}{\text{No. teeth}}$$

$$T_a = \frac{l}{F} \times \frac{l_a}{\pi D} \times \frac{1}{T}$$

L = length traveled by one tooth to dull cutter, in.
L = length of arc × number of chips
$L = l_a \times C_h$
a = axial-rake angle, deg
r = radial-rake angle, deg
γ = angle of inclination, deg
$\tan \gamma = \tan a \cos c - \tan r \sin c$
E = length of cutting edge engaged in cut, in.
$E = d \times \sec c \times \sec \gamma$
I = cutter life index, cu in. per in.

$$I = \frac{\text{Total volume metal removed}}{\text{Length of cutting edge engaged in cut} \times \text{no. teeth}}$$

$$I = \frac{V}{E \times T}$$

t = true or resultant rake angle, deg
$\tan t = \tan a \sin c \times \tan r \cos c$

One more development to which many engineers are looking forward is the increased application of the engineering mind to the social and economic problems the achievements of engineering have created. This can begin at home—in the human relations in the industry where engineers are employed, usually with executive responsibilities, often in what is called top management. To face human as well as mechanical realities, to understand the resources, and reactions, and relations of men as well as materials, to plan and organize the operations of men as intelligently as the operations of machines—all that is part of efficient engineering. Nor should engineers in planning for industry ignore the human consequences of their planning, the human readjustments that may be involved. This will be a part of engineers' duty in the future, I believe, more than it has been recognized to be in the past. Inside and outside industry, in community life, in the affairs of state and nation, where the increasing mechanizing of industry has far-reaching social and economic consequences, the engineer has his obligations. His training and experience and judgment are needed in civil and political life. An engineering age requires full use of the engineering mind.—From an address by R. M. Gates, Past-President A.S.M.E., before The Newcomen Society, American Branch.

CARBIDE MILLING *of* STEEL

By A. W. MEYER[1] and F. R. ARCHIBALD[2]

THE high-speed milling of steel with carbide cutters has presented an opportunity of conducting a very interesting investigation as to the most efficient feeds, speeds, and cutting angles that can be used under different operating conditions on various steels with a variety of grades of carbides.

In conducting such tests, we selected the manufacturing (bed-type) milling machine. This machine has a horizontal spindle with a standardized end having a No. 50 milling machine standard taper hole and is driven by a $7^1/_2$-hp spindle motor. Pick-off gears are provided from which it is possible to operate the spindle at speeds from 15 to 1000 rpm in approximate geometrical progression. The spindle axis, instead of being at a true right angle to the tableways, was adjusted to a slight angle by offsetting the spindle head 0.007 in. per ft, in order to prevent spoiling the finish on the test specimen. This provided a slight clearance for a face-milling cutter on what may be termed the "drag side" of the cut.

The table is driven by a 2-hp feed motor through pick-off gears which provides a range of feeds from 15/32 to 31 ipm, and the table drive includes an automatic backlash eliminator between the feed screw and feed nut.

The machine described was used for some preliminary cutting tests and later was equipped with a new spindlehead having increased horsepower and speeds, namely, a 40-hp motor and a speed range of 100 to 1800 rpm. Along with that change the gear ratio in the drive to the table was increased to double the feed rates previously mentioned so that feeds of 15/16 to 62 ipm are available.

The machine had the usual coolant arrangement so that tests could be conducted with or without coolants.

Tests have also been made on a second, slightly smaller, manufacturing-type machine, Fig. 1, similar in construction to the first machine, to expedite the test work and, in some cases, where test data came within the range and capacity of this machine to check and verify the results obtained on the first-mentioned machine. This smaller machine was originally provided with a 3-hp motor drive to the spindle with 20 speeds available from 25 to 1050 rpm and provided 28 feed changes from $^1/_2$ to 35 ipm. This spindlehead was also replaced to provide increased horsepower and higher spindle speeds, namely, $7^1/_2$ hp and speeds from 25 to 1870 rpm. A 1-hp feed motor was used in the drive to the table, which drive also included an automatic backlash eliminator.

In order to determine the machine efficiencies, horsepower tests were made at every speed. These tests, Fig. 2, were made using the customary water-cooled prony brake 24 in. diam × 6 in. face with conventional wattmeters, voltmeters, and ammeters.

STEELS SELECTED FOR TEST SPECIMENS

For the experiment, three different steels, S.A.E. 1010, S.A.E. 3240, and S.A.E. 4350, were selected. The S.A.E. 1010 at 90–100 Bhn was taken as representative of soft steel. The S.A.E. 3240, representative of medium-carbon steels in the annealed state, at about 200 Bhn. S.A.E. 3240 heat-treated to 320 Bhn was considered as representative of hard steel, and the S.A.E. 4350, capable of higher heat-treatment to 400 and 500 Bhn, was used as representative of extremely hard steel.

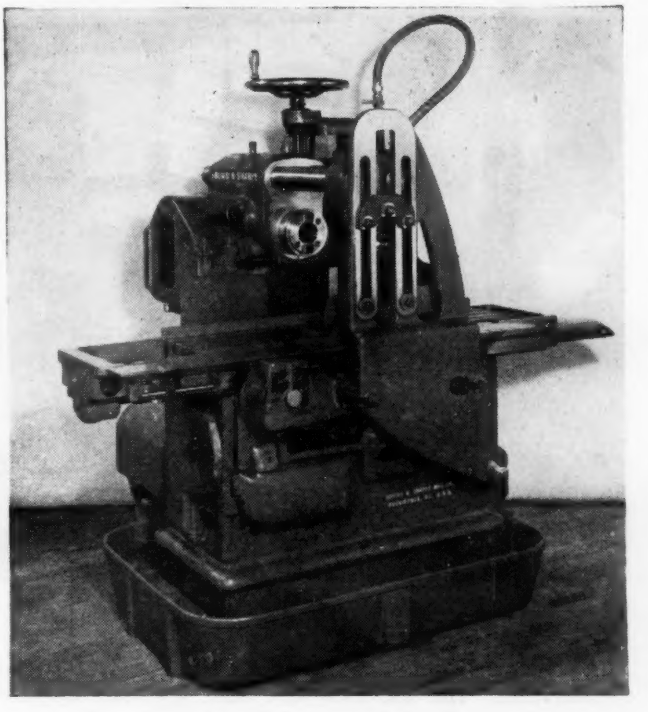


FIG. 1 TYPE OF MILLING MACHINE USED FOR CUTTING TESTS

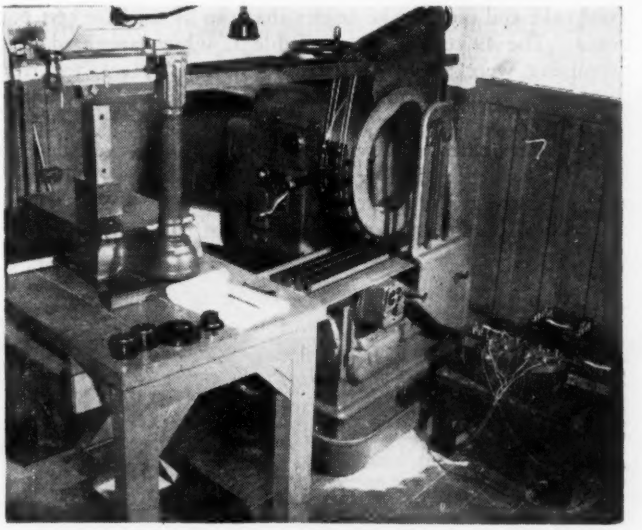


FIG. 2 TAKING EFFICIENCY TEST ON ONE OF THE MACHINES USED FOR CUTTING TESTS

The test specimens were approximately 3 in. × 5 in. × 30 in., the cutting being done, Fig. 3, across the end, usually with the spindle axis centrally positioned with the block, although some cuts were made with the cutter axis above and below the center line of the specimen in order to check the effect of entrance angle. The short repeated cuts taken across the end of the test block are considered typical of conditions usually encountered throughout the industry with the cutter entering and breaking out of the workpiece.

[1] Assistant Director of Design, Brown & Sharpe, Manufacturing Company, Providence, R. I. Mem. A.S.M.E.

[2] Experimental Department, Brown & Sharpe Company.

Contributed by the Research Committees on Metal Cutting Data and Bibliography, and on Cutting Fluids, and presented at the Chicago Section Meeting, Chicago, Ill., June 18–19, 1945, of The American Society of Mechanical Engineers.

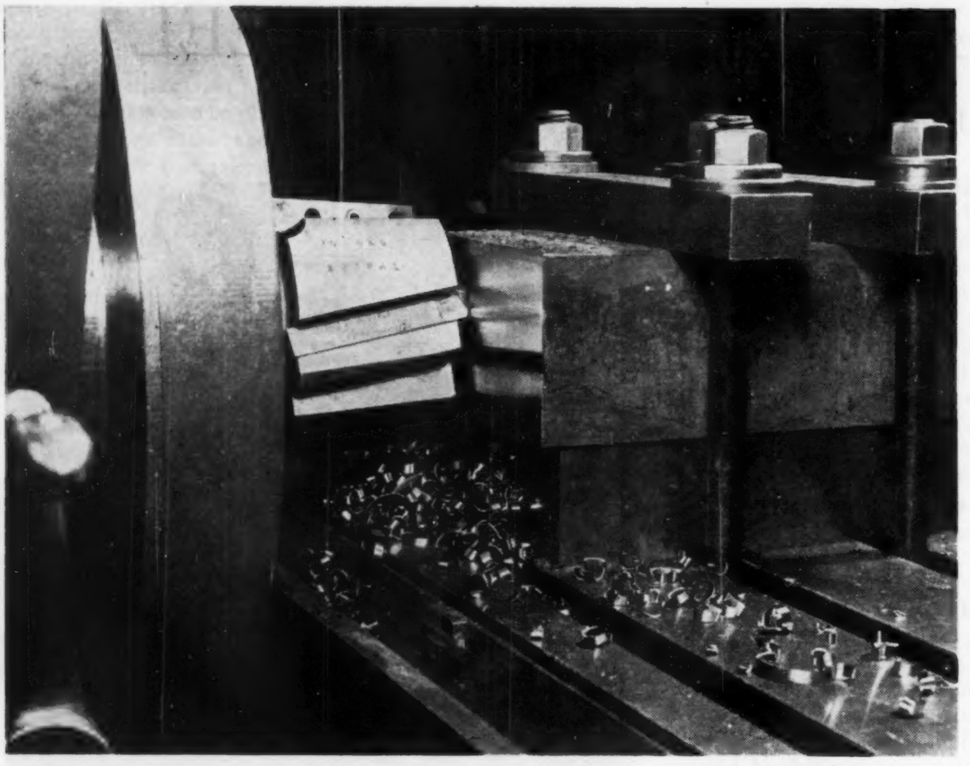


FIG. 3 METHOD OF MILLING TEST LOGS

TYPES AND SIZES OF CUTTERS

The types and sizes of cutters to be used were given careful consideration. The first tests were made with face mills of the fly-tool type with inserted teeth, as these were well adapted to have bits replaced at frequent intervals for experimental purposes, and many combinations could be tested with a minimum of expense and time. There are innumerable combinations of axial-rake and radial-rake angles that can be used for test purposes. The 49 combinations, Table 1, which appeared most promising were all evaluated, and we finally selected from these the 24 combinations at the outset, shown heavily underlined.

Six cutter bodies, each with four combinations, were made of steel and hardened all over to 65 to 70 scleroscope. The tools were held in place by three clamp screws.

In order to exhaust the possibilities of negative angles, we later made a cutter body to the following four angular conditions:

—15 Deg axial rake	—20 Deg radial rake
	—25 Deg radial rake
	—30 Deg radial rake
	—35 Deg radial rake

Fig. 4 shows the five cutter bodies in the first row and the one at the left-hand end of the second row as the six made originally. The second cutter body from the left in the second row is the one with extreme rake angles.

These cutter bodies were made to hold the fly tool at a radius of 2 in. from the cutter axis to produce what amounts to a 4-in-diam cutter. With maximum spindle speed of 1000 rpm, this gave a cutting speed of approximately 1100 fpm, somewhat above the speed range recommended by the makers of carbide materials.

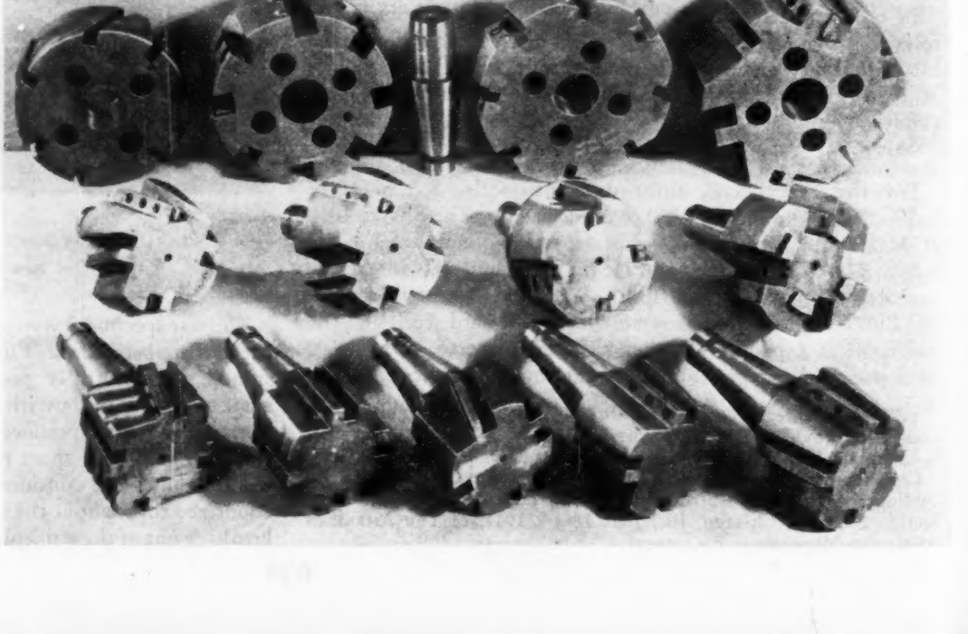


FIG. 4 FLY-TOOL AND MULTIPLE-TOOTH CUTTER BODIES USED IN TESTS

TABLE 1 TABLE OF AXIAL AND RADIAL RAKE ANGLES CONSIDERED

(Underlined combinations were made and tested)

AXIAL RAKE	RADIAL RAKE			
−15°	0°	−5°	−10°	−15°
−10°	0°	−5°	−10°	−15°
− 5°	0°	−5°	−10°	−15°
0°	0°	−5°	−10°	−15°
+15°	0°	−5°	−10°	−15°
+10°	0°	−5°	−10°	−15°
+ 5°	0°	−5°	−10°	−15°
0°		+5°	+10°	+15°
−15°		+5°	+10°	+15°
−10°		+5°	+10°	+15°
− 5°		+5°	+10°	+15°
+15°		+5°	+10°	+15°
+10°		+5°	+10°	+15°
+5°		+5°	+10°	+15°

The third cutter body from the left end in the second row is a four-tooth tool with —10 deg axial rake, —15 deg radial rake, which was made for multiple-tooth tests and to the same diameter as the fly tools.

The cutter body at the right-hand end of the second row was made to accommodate solid-carbide bits in four fly-tool positions, the particular angles selected being as follows:

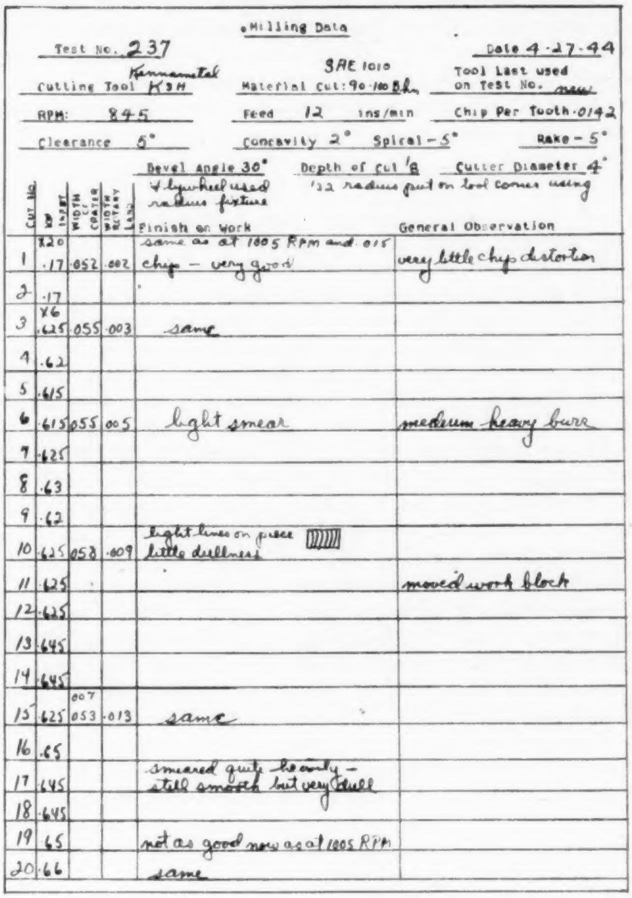
—10 Deg axial rake	—15 Deg radial rake
—10 Deg axial rake	— 5 Deg radial rake
— 5 Deg axial rake	— 5 Deg radial rake
— 5 Deg axial rake	—10 Deg radial rake

This cutter body was provided with an extra supporting section for the carbide bits at the end of the face mill.

Additional cutter bodies of larger diameter were also made in order to obtain comparative data on tool life.

In the upper left-hand corner is shown a cutter body 8 in. diam for use on a fly-tool cutter. This body was provided with seven blade-receiving slots as follows:

Axial rake	Radial rake
0 deg	0 deg
—10 deg	—10 deg
—10 deg	— 5 deg
— 5 deg	—10 deg
—20 deg	—10 deg
—20 deg	+10 deg
—35 deg	+15 deg



Milling Data

Test No. 237 — Date 4-27-44

Cutting Tool Kennametal K3H — Material Cut: SAE 1010 90-100 Bhn — Tool Last used on Test No. new

RPM: 845 — Feed 12 ins/min — Chip Per Tooth .0142

Clearance 5° — Concavity 2° Spiral −5° — Rake −5°

Bevel Angle 30° — Depth of Cut 1/8 — Cutter Diameter 4"

Flywheel used radius fixture — 1/32 radius put on tool corner using

Cut No		Width of Crater		Finish on Work	General Observation
1	X20 .17	.052	.002	same as at 1005 RPM and .015 chip – very good	very little chip distortion
2	.17				
3	X6 .625	.055	.003	same	
4	.62				
5	.615				
6	.615	.055	.005	light smear	medium heavy burr
7	.625				
8	.63				
9	.62				
10	.625	.058	.009	light lines on piece little dullness	
11	.625				moved work block
12	.625				
13	.645				
14	.645				
15	.625	.007 .053	.013	same	
16	.65				
17	.645			smeared quite heavily – still smooth but very dull	
18	.645				
19	.65			not as good now as at 1005 RPM	
20	.66			same	

FIG. 5 TEST SHEET USED TO MAKE ENTRY OF OBSERVATIONS AT TIME OF TAKING TEST CUTS

Adjacent to this is a cutter body of the same diameter for use as a multiple-tooth cutter. This was designed to accommodate eight 1-in-square bits in seats of —5 deg axial rake and +5 deg radial rake. It was proposed here to obtain any negative angles required by grinding the face of the carbide in a suitable manner.

The second cutter body from the right-hand end in the last row is also 8 in. diam and can accommodate eight 1/2-in-square bits held at —10 deg axial rake and —15 deg radial rake.

The bits in the three foregoing large-diameter cutters are held in position by means of wedges and screws.

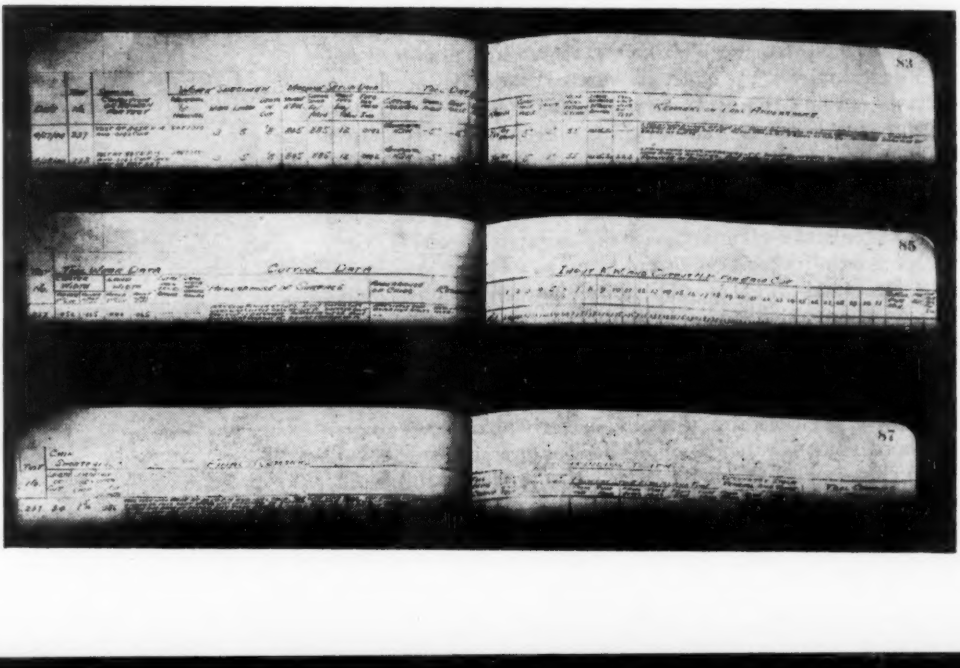


FIG. 6 RECORD BOOK CONTAINS DATA FROM TEST SHEETS WITH CONCLUSIONS

The cutter body shown in the upper right-hand corner in the last row is of 8 in. diam and operates as a fly tool. This has six blade-receiving slots, three to accommodate $^1/_2$-in-square shank bits, and three to accommodate 1-in-square shank bits. The three angular positions provided for each size bit are as follows:

— 5 Deg axial rake	—10 Deg radial rake
— 5 Deg axial rake	— 5 Deg radial rake
—10 Deg axial rake	—15 Deg radial rake

The object of this cutter body was to determine the effect of the difference in rigidity of the different size shanks.

The centering arbor used with the 8-in-diam cutter bodies is shown in the middle of the back row.

The tool bits used were stock $^1/_2$-in- and 1-in-square sizes as made regularly by the various manufacturers of cemented carbides. The solid bits used were $^3/_8$ in. $\times$ $^3/_4$ in. $\times$ $1^1/_2$ in.

The foregoing array of cutter bodies, the different materials to be machined, the selection of grades of carbides, and the many variables such as feeds, speeds, depth of cuts, use of coolants, flywheels, etc., necessitate a large number of test cuts being made to obtain complete and reliable performance data. The observations of each test and all essential details were recorded as the tests were conducted on forms as shown in Fig. 5. These were later tabulated, Fig. 6, together with calculated statistics such as horsepower per cubic inch, number of cubic inches of material removed, etc., along with noteworthy remarks and an entry made as to conclusions.

The depth of cut was standardized at $^1/_8$ in., although cuts of greater depth produce earlier tool failures under some conditions. However, the $^1/_8$-in. depth was selected since this did not consume an excessive amount of steel, and at the same time gave sufficient engagement to produce what can be considered as typical tool failures.

All of the tool positions in the cutter bodies outlined have been used to a considerable extent. At the outset, the cutters were operated with the selected angles, all other conditions being held constant, such as speed, feed, material of cutter, and material of work. When these initial test cuts had been completed, it was fairly obvious that many of the cutting positions could be rejected as not being of a promising nature.

CONDITION OF TOOLS AFTER TESTS

The positive axial rake - positive radial rake combinations were rejected owing to the rapid failure of the tools after the first few cuts. The severe fracture and complete breakdown of the tools in these instances are attributed to the weakness of the cutting edges.

The positive axial rake - negative radial rake group was rejected as it was found that these tools soon broke down at the end which has positive rake, and hence is also very weak. Fig. 7 is typical of such failures. This particular tool has +15 deg axial rake, —15 deg radial rake, 30 deg bevel, and was operated at 405 rpm, 425 fpm, $3^3/_4$-ipm feed, and 0.009-in. chip per tooth. Fig. 7 shows the condition of the tool after having taken 8 cuts in a test log of S.A.E. 3240 at 320 Bhn. The finish on the log was scratchy, typical of positive tools.

Another group discarded comprises cutters where the spiral angle exceeds the rake angle in the negative direction, e.g., —10 deg axial rake, —5 deg radial rake, —15 deg axial rake, —10 deg radial rake, etc. These were rejected, as such combinations of angles, in practically all cases, force the chip into the work, Fig. 8, thereby producing a scratched pattern on the milled surface which we term a "chip band."

This condition can be overcome by making the negative radial-rake angle greater than the negative axial-rake angle. The border line is reached when these angles are made equal, in which case we find a slight tendency to produce a chip band, especially when the tool is new or freshly sharpened. Use of a higher bevel angle provides a partial remedy, but this introduces other objections, such as end thrust, resulting in a tendency to recut.

Fig. 9 shows the condition of a tool after a test run in which the axial-rake angle was greater than the radial-rake angle. This tool operated at —15 deg axial rake, —5 deg radial rake, 30 deg bevel, 405 rpm, 425 fpm, $3^3/_4$-ipm feed, and 0.009-in. chip per tooth. The condition of the tool is shown, after having taken 17 cuts in a test log of S.A.E. 3240 at 320 Bhn.

Several additional angular conditions were also dropped from further consideration when tests indicated they were borderline cases with cutting-edge weaknesses or exhibited a tendency of producing chip bands. Fig. 10 shows a tool having 0 deg axial rake, —5 deg radial rake, 30 deg bevel, operated at 405 rpm, 425 fpm, $3^3/_4$-ipm feed, and 0.009-in. chip per tooth. After having taken 13 cuts in a test log of S.A.E. 3240 at 320 Bhn, this tool shows typical fracture at the inside end between wear lines and also excessive wear on the land.

As a result of observations made during the tests, the angular conditions that appeared most favorable when milling steel were reduced to the following five conditions:

FIG. 7 WEAK CUTTING EDGE, DUE TO COMBINATION OF ANGLES, RESULTS IN TOOL FRACTURE

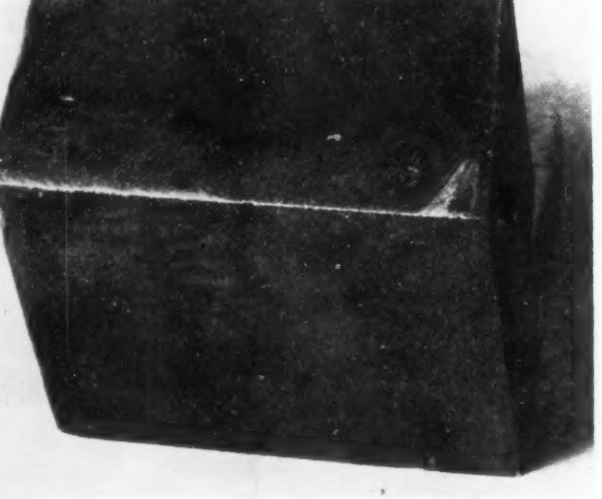


FIG. 8 TEST SPECIMEN SHOWING CHIP BAND

(*a*) —10 Deg radial rake — 5 Deg axial rake
(*b*) —10 Deg radial rake —10 Deg axial rake
(*c*) —15 Deg radial rake 0 Deg axial rake
(*d*) —15 Deg radial rake — 5 Deg axial rake
(*e*) —15 Deg radial rake —10 Deg axial rake

Of these, condition (*e*) was the most satisfactory from the standpoint of tool life and finish. Fig. 11 shows the condition of the tool after having taken 60 cuts in S.A.E. 3240 test log at 320 Bhn. This tool has —10 deg axial rake, —15 deg radial rake, 30 deg bevel, and was operated at 275 rpm, 288 fpm, $3^3/_4$ ipm feed, and 0.0142-in. chip per tooth. The cuts were on a test log 3 in. wide × 5 in. long, the depth of cuts being $^1/_8$ in.

SOFT STEELS

On very soft steel, we found when face-milling S.A.E. 1010 below 100 Bhn, that satisfactory results were obtainable with much less negative conditions. For example, Fig. 12 shows a tool after having taken 55 cuts $^1/_8$-in. deep in a 3-in. × 5-in. test log of S.A.E. 1010 at 95 Bhn. This tool has —5 deg axial rake, —5 deg radial rake, 30 deg bevel, and is operated at 845 rpm, 885 fpm, 12-ipm feed, and 0.0142-in. chip per tooth.

This is a somewhat special case as steel of such low Brinell hardness is not too frequently encountered, although we do use such materials in components that enter into magnetic equipment.

Of the remaining four angular conditions mentioned, it was found that (*a*) —10 deg radial rake, —5 deg axial rake, and (*d*) —15 deg radial rake, —5 deg axial rake have weaker cutting edges than the (*e*) —15 deg radial rake, —10 deg axial rake cutters, with no other compensating advantages. Cutters (*b*) with —10 deg radial rake and —10 deg axial rake had a slight tendency to produce chip bands, and cutters such as (*c*) with —15 deg radial rake and 0 deg axial rake in our opinion are too weak at the end owing to the 0 deg axial rake.

The possible merit of greater negative angles than —15 deg axial rake, —15 deg radial rake, was explored by use of a cutter body previously mentioned, having with the —15 deg axial rake, —20 deg radial rake, —25 deg radial rake, —30 deg radial rake, and —35 deg radial rake.

Fig. 13 shows a tool of the extreme negative condition which was tested. This has —15 deg axial rake, —35 deg radial rake, 30 deg bevel which actually cuts with a true rake of $—37^1/_2$ deg. Tests were run at 275 rpm, 288 fpm, $3^3/_4$-ipm feed, and 0.0142-in. chip.

Five cuts were taken in S.A.E. 3240 at 320 Bhn. This tool was not considered satisfactory, although it cut fairly well. The high rake in such a tool results in heavy end thrust with its resultant tendency to drag excessively or to recut, thereby producing an unsatisfactory finish. Apparently the excessive pressures developed by cutting with such high negative rakes cause breakdown of the cutting edge. It has been found in this work involving extremely high negatives, that —15 deg axial, —15 deg radial rake, is about as high as it is desirable to go and that gives, with a 30 deg bevel, a true rake of slightly over —20 deg.

USE OF COOLANTS

We have conducted steel-cutting tests with the use of coolants, both water emulsions and oil. Our observations indicate that some improvement in finish is occasionally obtained when oil coolants are used, but the quenching action on the tool affects its life to such an extent that we prefer not to use an oil coolant when milling steel.

Fig. 14 is illustrative of the condition of tools after having taken only one cut in a steel test log of S.A.E. 3240 at 320 Bhn. This cutter was used with water emulsion and has —10 deg axial rake, —5 deg radial rake, 20 deg bevel, 405 rpm, 425 fpm, and operated at $3^3/_4$-ipm feed, 0.0093-in. chip per tooth. In spite of its condition, this tool produced a good finish. Tools ground to the same angles and used under identical conditions, but with oil as a coolant instead of water emulsion, fractured badly.

Fig. 15 shows the condition of such tools after having been used for a half-dozen cuts, with oil as a coolant. The stresses due to quenching action evidently caused the fracture clearly shown between the wear lines which resulted in the early failure of this tool.

Fig. 16 shows a tool operated at excessive speed. This was used on an S.A.E. 3240 test log with 190 Bhn. The tool has —10 deg axial rake, —15 deg radial rake, 30 deg bevel, and was operated at 710 rpm, 744 fpm, $9^5/_8$-ipm feed, 0.0135-in. chip load. This tool made 17 cuts $^1/_8$-in. deep; the finish on work was smeared and the tool gives evidence of excessive land growth as well as a rather deep crater. Fig. 17 illustrates a tool used with too little bevel, i.e., a bevel of 15 deg. The tool is shown after having taken two cuts in a steel test log of S.A.E. 3240 at 320 Bhn with —10 deg axial rake, —15 deg radial rake, operated at 275 rpm, 288 fpm, $3^3/_4$-ipm feed, 0.0142-in. chip per tooth.

One of the most surprising things encountered in these tests has been the great influence of the bevel angle on tool life. Where, with the use of high-speed steel cutters, sharpening has generally been to a sharp corner with a slight chamfer, or no chamfer at all, carbides have been found to be very unsatisfactory to use with low bevel angles. Our tests indicate that angles below 30 deg are rather impractical, but we have used 30-deg bevels with quite consistent success. Higher bevels can be used; 45-deg bevels are quite satisfactory but begin to show a tendency to recut due to increased end thrust. We have tried 60-deg bevel angles, but the effect of end thrust was found to be very pronounced, and the tendency of the chip to warp and to foul the cutting edge was so great that we consider bevel angles above 45 deg unsatisfactory in so far as steel milling is concerned.

We have made tests using solid carbide blades, and Fig. 18 shows such a tool following a run of 40 cuts on a steel test log of S.A.E. 3240 at 320 Bhn. This shows crater cracks and fracture.

The results usually were not as good as those obtained with a cutter having brazed tips, in which case the condition of the tool, Fig. 19, was better after a run of 60 cuts. This difference is accounted for by the fact that we found the solid bits to be slightly harder—about half a point on the Rockwell A scale—than the brazed bits in the same grade.

HARD STEELS

In the milling of extremely hard steels it was found that carbide tools soon failed.

Fig. 20 shows a tool with —10 deg axial rake, —15 deg radial rake, 30 deg bevel, operated at 175 rpm, 183 fpm, $2^9/_{16}$-ipm feed, 0.0146-in. chip per tooth. This tool fractured badly before completion of a single cut on a 3-in. × 5-in. test log of S.A.E. 4350, heat-treated to 500 Bhn. Another similar tool, operated at $^1/_2$-ipm feed, with 0.0053-in. chip load, ran for 3 cuts with the same results, and tool fracture.

The hardest grade of steel-cutting carbide was also tested using the same axial and radial rake and bevel angles, but with the speed reduced to 95 rpm, or 100 fpm. A feed rate of $^1/_2$ ipm was used, and a chip load of 0.0053 in. Fig. 21 shows the condition of the tool after having taken two cuts on a test log with small fractures making their appearance.

High negative radial rakes were also tested, and Fig. 22 shows such a tool which has a —15 deg axial rake,—35 deg radial rake, 30 deg bevel. This tool operated at 95 rpm, 100 fpm, at $^1/_2$-ipm feed with 0.0053-in. chip, fractured as shown, in two cuts.

Tests were run with the 8-in-diam fly tools to make comparisons with the smaller fly tools of 4 in. diam. In all cases it was found that better performance was obtained from the

FIG. 9 TOOL USED WITH AXIAL-RAKE ANGLE GREATER THAN RADIAL-RAKE ANGLE

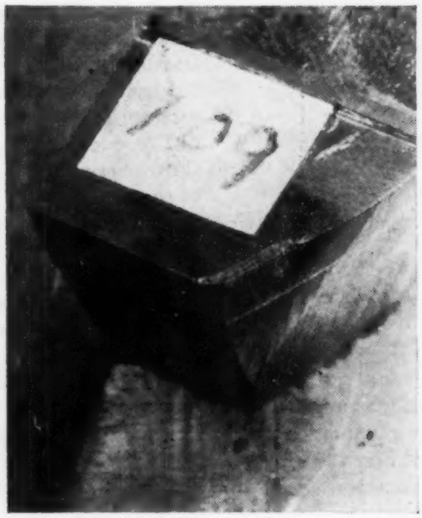


FIG. 10 TOOL FRACTURED AT WEAR LINES

FIG. 11 TOOL USED WITH SATISFACTORY ANGLES AND UNDER PROPER OPERATING CONDITIONS

FIG. 12 TOOL USED IN CUTTING SOFT STEEL

FIG. 13 TOOL USED WITH EXTREME NEGATIVE ANGLES

FIG. 14 TOOL USED WITH WATER EMULSION

FIG. 15 TOOL USED WITH OIL AS COOLANT

FIG. 16 TOOL OPERATED AT EXCESSIVE SPEED

FIG. 17 TOOL WITH INSUFFICIENT BEVEL

FIG. 18 SOLID-CARBIDE TOOL BIT (Compare with Fig. 19.)

FIG. 19 BRAZED-CARBIDE TOOL BIT (Compare with Fig. 18.)

FIG. 20 TOOL USED IN MILLING EXTREMELY HARD STEEL

FIG. 21 TOOL WITH SMALL FRACTURE AFTER TWO CUTS WERE TAKEN ON EXTREMELY HARD STEEL

FIG. 22 TOOL USED WITH HIGH NEGATIVE RADIAL RAKE

smaller cutters. When tool life is considered, we found that "wear" was the determining factor with the 4-in. cutter, whereas tool "fracture" was invariably the termination of tool life of the 8-in. cutter.

It may be objected that entrance conditions were altered by change in diameters, but corrective steps were taken to compensate for this, such as raising the work relative to the center of the cutter to maintain the same entrance conditions, and doubling the thickness of the test block, in order to obtain a proportional enlargement of a 4-in. cutter operating on small blocks. Under all such conditions it was found that there is a definite advantage in cutters of the small diameter.

For fly-tool work, originally it was found essential to use a flywheel to overcome the objectionable gear hammer in the spindle train as the cutter tooth emerged from the cut. The flywheel used, made of steel, was 24 in. diam, $1^5/_{16}$ in. thick, weighing approximately 165 lb. This was mounted at the spindle nose.

MULTIPLE-TOOTH CUTTERS

Multiple-tooth cutters have also been run, made to 4-in. diam with 4 teeth, 4-in. diam with 6 teeth, 8-in. diam with 8 teeth for $^1/_2$-in-square tools, and 8 in. diam with 8 teeth for 1-in-square tools.

These all confirm experience previously gained with fly tools. Indications are, however, that the multiple-tooth cutters perform somewhat better than fly tools. They seem to have slightly less tendency to wear. With such cutters a new difficulty is encountered, i.e., that of having a high tooth which affects finish. Special care was taken to have the tools run true in the machine so that the ends of the teeth were within 0.0002 in. of "tracking," or being in the same plane.

Fig. 23 shows the condition of teeth in a 4-tooth cutter having a —10 deg axial rake, —15 deg radial rake, 30 deg bevel, operated at 265 rpm, 277 fpm, 15-ipm feed and 0.014-in. chip per tooth. This cutter took 300 cuts in an S.A.E. 3240, 320-Bhn test log, and it had reached the point at which it required resharpening. Based on fly-tool experience of 60 cuts, these tools could have been expected to take 240 cuts. Hence it may be concluded that the multiple-tooth cutter has given a more favorable performance with a run of 300 satisfactory cuts.

Fig. 24 shows, as a comparison, the condition of the cutting teeth run in an 8-tooth body. This cutter had —10 deg axial rake, —15 deg radial rake, the same as in Fig. 23, and 30 deg

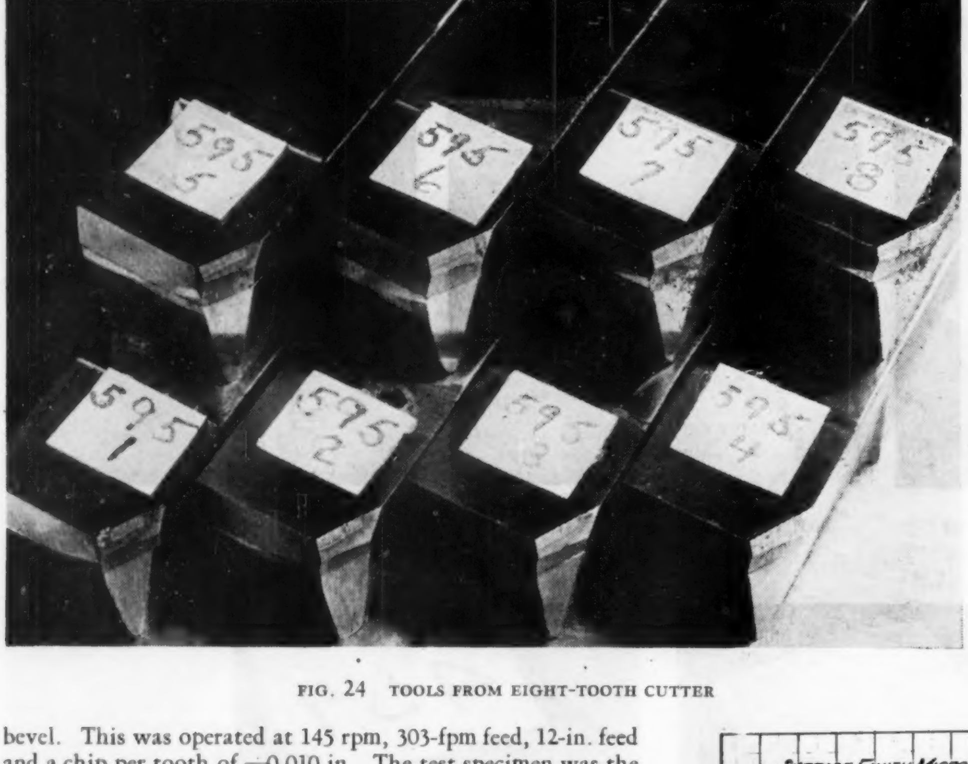


FIG. 24 TOOLS FROM EIGHT-TOOTH CUTTER

bevel. This was operated at 145 rpm, 303-fpm feed, 12-in. feed and a chip per tooth of —0.010 in. The test specimen was the same, namely, S.A.E. 3240 at 320 Bhn. This cutter took 420 cuts, ending in fracture. If performance is to be based on a par with the cutter previously mentioned, this cutter should have taken 600 cuts. Although the chip per tooth was slightly less, 0.010 in. against 0.014 in., slightly greater wear may be expected, but failure, it may be noted, is due to fracture.

FINISH OBTAINED

In testing with a fly tool, Fig. 25, the finish is generally bright and clear for the first five cuts. After that the finish becomes streaked and smeared in appearance. Although the surface is still smooth and actually shows a lower profilometer reading at this stage, it is not as pleasing to the eye and gradually becomes rougher.

With multiple teeth the inaccuracies of locating the teeth give sufficient roughness to the surface to mask this deterioration in finishing of an individual tool. The result is that the finish with multiple teeth remains nearly constant throughout the life of the cutter. Fig. 26 shows test specimen following the 300th cut with an 8-in-diam cutter having 8 teeth; revolution marks are in evidence and have a marked effect on the appearance of the finish.

Profilometer readings on the finish produced by multiple-tooth cutters are about 150 microinches (rms) at the start and fall to 120 microinches after 100 cuts. It should be borne in mind, however, that the kind of finish being produced is really not suitable for profilometer readings, so the meaning of the readings is doubtful.

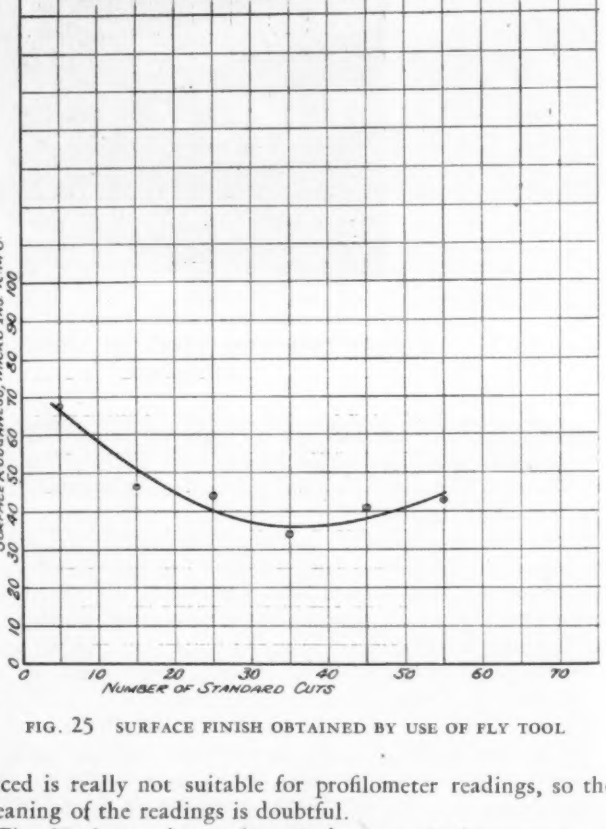


FIG. 25 SURFACE FINISH OBTAINED BY USE OF FLY TOOL

Fig. 27 charts observations made as to the horsepower required per cubic inch per minute for various negative-rake conditions. The points plotted were obtained from fly-tool tests where these tools were placed at widely different component angles including the positive-negative combinations. The chart shows a gradual increase in power consumption from about 0.75 hp per cu in. with 0 deg true rake to about

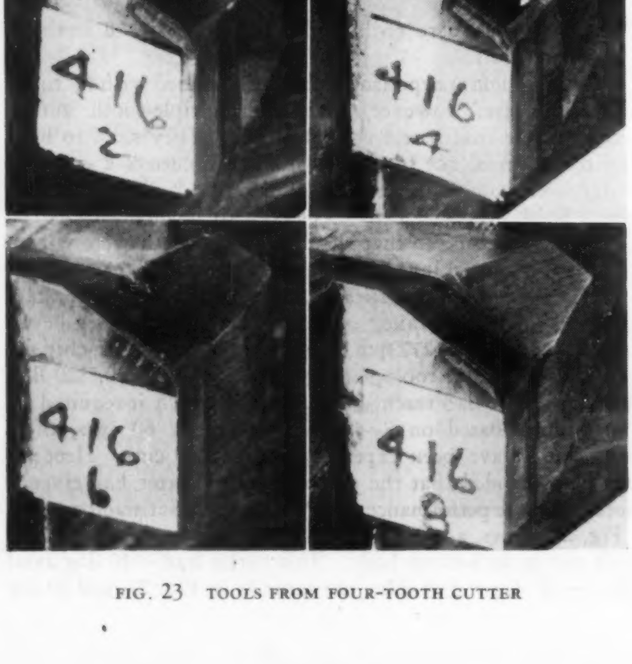


FIG. 23 TOOLS FROM FOUR-TOOTH CUTTER

0.9 hp per cu in. at —20 deg true rake. These power readings were all taken at the same time in each instance, that is, at the second cut, in order to be sure that the tool was sharp and that the depth of cut was accurate, for at the first cut the depth is very apt to be somewhat uncertain and variable.

Fig. 28 is a chart showing rates of land growth, indicating the growth to be greater on the softer steels.

CONCLUSIONS

The tests would indicate that for face-milling of extremely soft steels, such as S.A.E. 1010 below 100 Bhn, the following conditions were most satisfactory: —5 deg axial rake, —5 deg radial rake, 30 deg bevel, 5 deg clearance, 2 deg concavity, $^1/_{16}$-in. corner chamfer (approximate), 0.010 to 0.015-in. chip per tooth, and 850 fpm.

For moderately soft steels, such as S.A.E. 1020 at 140 Bhn the following conditions are most satisfactory: —10 deg axial rake, —15 deg radial rake, 30 deg bevel, 5 deg clearance, 2 deg concavity, $^1/_{16}$-in. corner chamfer (approximate), 0.010- to 0.015-in. chip per tooth, 550 fpm speed.

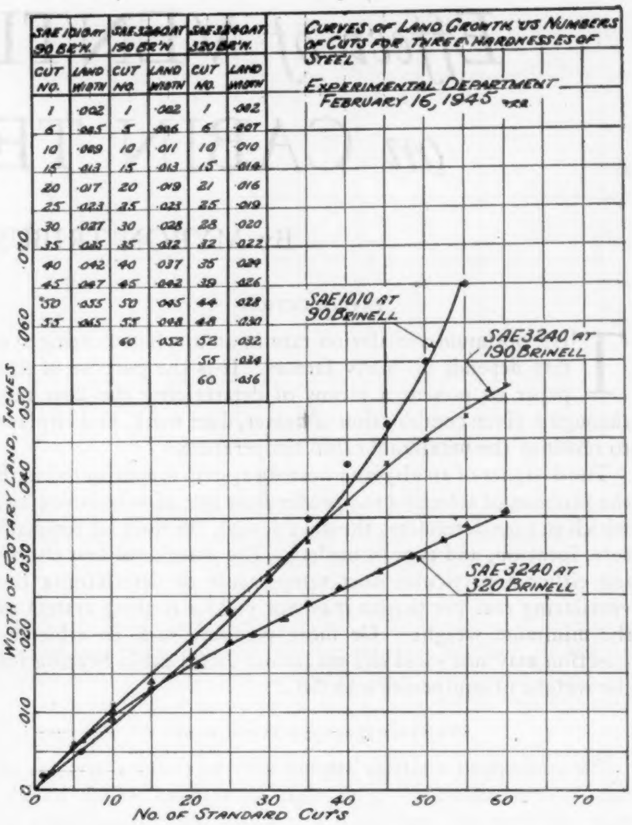


FIG. 28 CHART INDICATING LAND GROWTH WITH STEELS OF DIFFERENT HARDNESS

For steels of medium hardness, such as annealed S.A.E. 3240 at 200 Bhn, the following conditions are most satisfactory: —10 deg axial rake, —15 deg radial rake, 30 deg bevel, 5 deg clearance, 2 deg concavity, $^1/_{16}$-in. corner chamfer (approximate), 0.010- to 0.012-in. chip per tooth, 350-fpm speed.

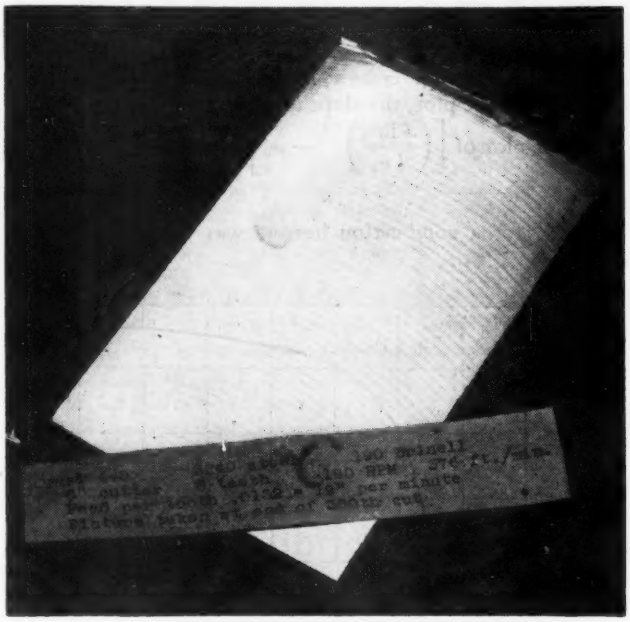


FIG. 26 TEST SPECIMEN SHOWING FINISH OBTAINED WITH MULTIPLE-TOOTH CUTTER

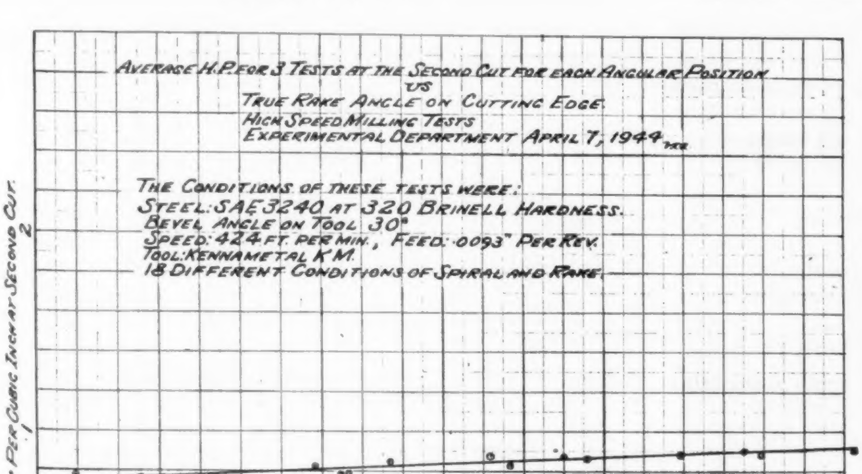


FIG. 27 CHART INDICATING HORSEPOWER USED UNDER DIFFERENT CONDITIONS

For heat-treated steel such as S.A.E. 3240 at 320 Bhn, the following conditions are most satisfactory: —10 deg axial rake, —15 deg radial rake, 30 deg bevel, 5 deg clearance, 2 deg concavity, $^1/_{16}$-in. corner chamfer (approximate), 0.010-to 0.012-in. chip per tooth, speed not over 300 fpm.

In this presentation, an attempt has been made to call attention to some of the principal factors entering into the application of carbides in milling. Some of the points covered are admittedly controversial, and it may well be that some readers have had experiences which deviate from that which has been outlined.

At the outset, one gains the impression that considerable is known about the subject, but as the experimental data are tabulated further, and additional questions arise, it is soon realized that there is much yet to be learned from the many unknown factors, and that each job requires individual engineering.

Effect of VENTILATION RATE *on* CABIN TEMPERATURE

By MYRON TRIBUS[1] and AVERY FOOTE[2]

INTRODUCTION

THE optimum ventilation rate in an airplane heating system depends on many factors. It is the purpose of this paper to present a means of determining the flow rate through a given combination of heater, duct work, and airplane to result in the maximum cabin temperature.

The designer of an airplane heating system is confronted with the problem of selecting the proper flow rate of ventilating air, which in turn determines the duct design, the duct air temperature, location, and type of outlets. The practice of first choosing either a particular duct temperature or determining the ventilating rate per person may not yield a heating system of the minimum weight. Or more precisely such an arbitrary selection may not yield the maximum useful cabin heating for the weight of equipment selected.

VENTILATING-AIR FLOW RATE

The subsequent analysis applies only to heating systems of the "nonrecirculating" type, that is, systems which handle only air from the outside. The following nomenclature is used:

C_p = specific heat of air, Btu per lb per deg F
q = heater output, a function of ventilating-air rate, Btu per hr
θ = temperature of airplane cabin air, measured above the ambient air temperature, deg F
ΣUA = summation of heat-transfer conductances for enclosing walls of airplane cabin
$\Sigma UA = U_1A_1 + U_2A_2 + U_3A_3 + \ldots\ldots$
U_1A_1 = conductance of total glass area
U_2A_2 = conductance of total insulated-wall area
U_3A_3 = conductance of total floor area
w_v = flow rate of ventilating air, lb per hr
w_e = leakage-air flow rate, outside air into cabin, lb per hr

Any consistent set of units may be used in place of those indicated.

The heater output is used for the following purposes:

1 Heating ventilating air up to cabin temperature
$$w_vC_p\theta$$
2 Heating leakage air up to cabin temperature
$$w_eC_p\theta$$
3 Supplying heat loss through enclosing walls
$$\theta\Sigma UA$$

$$q = w_vC_p\theta + w_eC_p\theta + \theta\Sigma UA$$

The cabin temperature can be expressed in terms of the other variables

$$\theta = \frac{q}{w_vC_p + w_eC_p + \Sigma UA}$$

Taking first the logarithm, differentiating with respect to w_v, and setting the derivative equal to zero gives

$$\left(\frac{d \ln q}{dw_v}\right)^{-1} - w_v = w_e + \frac{\Sigma UA}{C_p}$$

For a given set of inlet conditions, the left-hand term can be plotted as a characteristic curve of the heater. The plot is constructed in the following manner:

(*a*) The heater output is determined as a function of w_v, Fig. 1.
(*b*) A plot of ln q versus w_v is constructed.
(*c*) From the plot, the slope of the curve is determined.
(*d*) A plot of $\left[\left(\frac{d \ln q}{d\, w_v}\right)^{-1} - w_v\right]$ versus w_v is constructed, Fig. 2.

Fig. 3, for a combustion heater, was constructed in this manner.

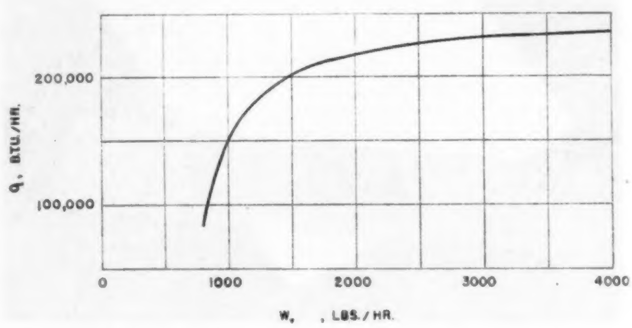


FIG. 1 HEAT OUTPUT VERSUS VENTILATING-AIR RATE

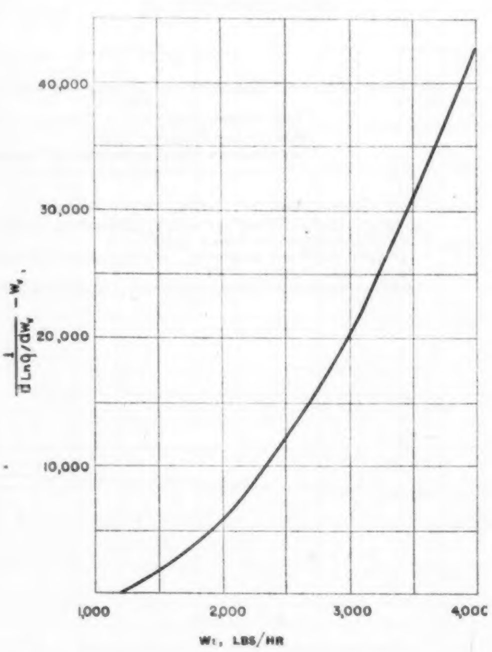


FIG. 2 SOLUTION OF EQUATION $\left(\frac{d \ln q}{d\, w_v}\right)^{-1} - w_v = w_e + \frac{\Sigma UA}{C_p}$

[1] Captain, AAF Air Technical Service Command, Wright Field, Ohio.
[2] Regional Engineer, Frigidaire Division, General Motors Corporation, Oakland, Calif.

Contributed by the Heat Transfer Division and presented at the Annual Meeting, New York, N. Y., Nov. 27–Dec. 1, 1944, of The American Society of Mechanical Engineers.

DISCUSSION

In use the designer estimates the value of the term $w_e + \Sigma UA/C_p$ and determines from the curve the optimum value of w_v. In the case of a combustion heater it can be seen that there is a value of w_v beyond which it never pays to go.

For example, the cargo compartment of a C-46 airplane is found to have a value of ΣUA = 550 Btu per hr per deg F, when insulated in a particular manner. The relation between optimum air flow and air leakage for the heater described in Fig. 1, is computed as shown in Table 1.

TABLE 1 CALCULATIONS SHOWING RELATION BETWEEN OPTIMUM AIR FLOW AND AIR LEAKAGE FOR HEATER USED IN CARGO COMPARTMENT OF A C-46 AIRPLANE

Leakage, lb per hr, w_e	$\frac{\Sigma UA}{C_p} + w_e$ lb per hr	w_v Optimum, lb per hr	q Btu per hr	Temperature rise of ventilating duct, deg F	θ Resultant cabin temperature rise, deg F
0	2280	1580	206000	541	221
500	2780	1660	209000	522	195
1000	3280	1730	212000	509	176
1500	3780	1780	214000	500	160
2000	4280	1840	214500	484	145
2500	4780	1900	215000	470	133
3000	5280	1960	217000	460	124
5000	7280	2130	220000	429	97
10000	12280	2500	226500	376	63.5
20000	22280	3100	230000	308	37.6

Fig. 3 shows graphically the relation between optimum flow rate, leakage, and cabin temperature. It will be noted that leakage w_e has little effect on the optimum ventilating rate w_v hence, the estimate of the term $[w_e + (\Sigma UA)/C_p]$ is not difficult. As a result of these calculations, it is noted that the resultant duct air temperatures (see Table 1) are higher than those normally used in aircraft. This indicates the need for re-entrant-type exits to produce efficient mixing, or may require that a ventilation rate other than optimum be used.

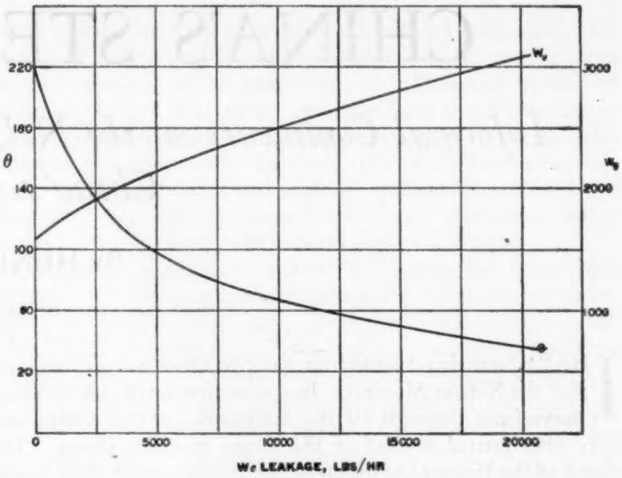


FIG. 3 RELATION BETWEEN OPTIMUM VENTILATING-AIR FLOW, LEAKAGE RATE, AND CABIN TEMPERATURE FOR C-46 AIRPLANE AND HEATER COMBINATION

The foregoing analysis is valid only when the following conditions prevail:

(*a*) There is some definable θ, a mean cabin temperature.

(*b*) All the air leaving the cabin leaves at the cabin temperature.

A similar analysis can be made for the primary- and secondary-air streams in cabin-heating systems employing secondary exchangers.

Grease Lubrication of Ball-Bearing Motors and Generators

(*Continued from page 644*)

will prove the investment well worth while. Good example starts at the top.

Provision must be made for proper storage facilities which make it possible to keep all lubricants clean. A room should be specially provided for this purpose, planned so that containers in use are easily accessible. It should be possible to clean thoroughly and easily at any time.

If lubricants of necessity are further distributed through the plant, storage facilities, such as steel cabinets, should be provided.

Personnel. Men chosen for the work of applying lubricants should be hand-picked. Some men are naturally clean and neat as well as methodical. If this type can be found it would be well to place them in this group. Sloppy men do sloppy work and the care of expensive equipment should not be placed in their hands.

They should have mechanical training. During the work of applying lubricants a good mechanic will often detect mechanical trouble before it becomes serious. Trouble caught in its early stages might cost a few dollars for adjustment but if not noticed, would eventually cost a considerable sum.

Too many instances are noted in which this type of work is handed to the men with the lowest hourly rate. Better judgment than this should be practiced.

CONCLUSION

This is a general over-all picture of the many angles involved in the problem of lubrication of ball-bearing motors. Any phase warrants considerably more treatment than is offered in this paper. It is hoped that a great deal more material on this subject will be forthcoming.

Ball and roller bearings are today considered to be a critical part of the nation's war-effort stock pile. Improper maintenance that results in bearing-replacement withdrawals from this stock pile definitely calls for study and great interest on the part of everyone concerned.

The cost of the replacement bearing itself is only a small part of the cost in lost production and the consumption of valuable man-hours needed to correct the results of improper maintenance which in most cases, could be avoided.

Close study of shop repair orders and the equipment coming in for overhaul would undoubtedly reveal much laxity in the application of proper practices in lubrication-preventive maintenance.

Since we are all interested in extending the life of antifriction bearings to the maximum years of service, we must work together to this end; the bearing manufacturers, the equipment builders, the lubricant producers, and the eventual users.

ACKNOWLEDGMENT

The author wishes to acknowledge the co-operation and counsel of many research and production engineers of electric-motor manufacturers, as well as the engineers and metallurgists of ball-bearing manufacturers, over a period of several years. It has all been greatly appreciated. Figs. 2 to 5, inclusive, are published through the courtesy of SKF Industries, Inc., and Fig. 6 is published through the courtesy of Fafnir Bearings, Inc.

CHINA'S STEEL INDUSTRY

Informal Comments on the Nelson Mission and an Expression of China's Appreciation

By HENRIK OVESEN

LUKENS STEEL COMPANY, COATESVILLE, PA., MEMBER A.S.M.E.

I HAVE recently returned from a trip to China as chief engineer for the Nelson Mission. In connection with this service I have been through all the steelworks in Free China and have also visited several of the larger machine shops. The object of the trip was to diagnose the troubles with the Chinese steel industry and endeavor to set it in motion.

The mission worked under the general direction of Dr. Wong, Wen-Hao, the minister of economic affairs, who had delegated very able Chinese industrialists to take chairmanships of the various committees formed under the newly created Chinese WPB. Such men were Y. C. Sun for coal and coke, C. S. Wang for ore, F. Chen and M. S. Pai for power. Meetings were held and discussions took place covering all steps leading to increased production and improvements which could be made quickly and without importations from abroad.

It must be remembered that the part of China which is now Free China is poor in so far as means of communication is concerned, and, worse than this, the quality of raw materials for steelmaking is not all that could be desired. The Chinese decided in 1936 to move their arsenals to the vicinity of Chungking and in this moving they have performed unbelievable feats. For example, they have taken a boiler and a 2500-kw turbogenerator apart, loaded them on river craft, shipped them 1500 miles up the Yangtsekiang, and re-erected them without missing a part! They have built several small blast furnaces, 25 to 30 tons' capacity per 24 hours, and also Bessemers of 2 tons' capacity and a few open hearths of 10 tons' capacity, all feeding steel to small rolling mills. Most of the furnaces have been built of plate salvaged from river steamers, and the boilers from steamers are in evidence everywhere. The mills can probably produce 50,000 tons per year if operated to full capacity.

Chinese machine shops are generally equipped with German machine tools of light design, and, in the arsenals, specialized to the limit.

In absence of automatic screw machines they use light lathes with hand feed and generally operated by an apprentice boy who gains remarkable skill in his repetitive work.

There is great reluctance to work 24 hours. This is blamed on inability to get men, but it is probably more an old Chinese custom to be at home at night which is the reason.

We did not see any machine shops working the night shift. The private machine shops seem to be in hands of energetic managers or owners. The largest is the Ming-Sung Engineering Works headed by Mr. Lu Tso-Fu. This plant has machine tools for large and heavy work and is connected with a shipyard. Some American machine tools were found here, although most of them were rather old.

In Kunming is another large machine shop set up by the N.R.C. It is a rather complete establishment having an iron and steel foundry, boiler shop, electrical shop, and a machine shop with fair equipment.

The government through an agency, N.R.C., National Resources Commission, owns the greater part of the steelworks, an up-to-date refractories plant, and some machine shops. The government also owns all the arsenals, and the War Ministry and N.R.C. each owns one half of the largest, Ta-Tu-Kuo, which has a 100-ton and a 30-ton blast furnace, two 10-ton open hearths, a Bessemer, two electric furnaces, a 2.5-meter plate mill, and a structural mill.

Government ownership is not better liked in China than in the United States, and it is not as efficient as the private companies.

Besides the 25-ton blast furnaces at the steelworks there are, in the Province of Szechuan, several hundred of 1-ton charcoal blast furnaces operated by the farmers during the period of the year when the farm does not require attention. These "native" producers deliver about 1 ton per 24 hours and this iron is very pure. It can be produced for about one half the cost of the steelworks pig iron and is therefore easily disposed of.

The question was raised several times by the Chinese managers and owners: What to do with Chungking's steel industry after the war? The answer could only be an evasive one: Can you compete with a plant in Hankow or Shanghai? It is our belief one of the privately owned works may remain but the bulk of steel can be imported at a lower cost than the district can meet. In other words, this industry is purely a temporary expedient. Even should there be a market here in coming years, the plants are all built so it will be difficult to expand, owing to the terrain and to the fact that the men locating the plants evidently never thought that expansion might be desirable.

All transportation today is based on the rivers, and with a difference between high-water season and low-water season of close to 90 ft, the harbor question alone offers difficulties. Today all material—ore, coke, coal, stone, etc.—is carried by coolies up these banks and the finished material is carried down them; but this must also be changed to cut down expenses.

Last but not least it must be remembered that practically all of the executives and many of the skilled men are refugees, and inasmuch as not only materials and works but living conditions too are better where they came from, they will probably move back when occupied China is freed again.

As an emergency the Chinese have performed a commendable piece of work, but the central, northern, and eastern sections of China will reap the benefit of the experience gained in the refugee regions.

The arsenals will probably remain here for safety's sake. It is my opinion it will take many years to get China industrialized if the United States or others do not step in and build and partly man steelworks, foundries, and machine shops, until the Chinese have developed a number of foremen who can carry on. The lack of these seems to be the greatest drawback in the works today. After the war there should be a tremendous market for modern machine tools, cement plants, and woodworking machinery, and it may well be possible to dispose of our used machine tools, thus enabling the makers to take used tools in trade-ins for new designs of tools to be sold to American machine shops.

There should also be a big market for modern road-building machinery as the immense hinterland is poorly provided with highways and the existing ones are none too good.

If a low-cost engine can be developed for the river junks loading from 40 to 60 tons, it will be in demand, as labor in

China is not cheap any more and these junks require from 10 to 16 men. Waterways will always play a large role in the country's transportation system. There will be a demand for some railroads too, but the cost of building railroads in the western provinces is high because of the terrain.

There is much to do in China and some of the people are aware of it. Hundreds of Chinese are in the United States now and more are coming to study our methods in industry. We found a welcome wherever we went and on our last day the Chinese engineering societies gave a luncheon in our honor. A speech by Minister of Communications Tseng Yang-Fu was delivered at this luncheon. We are all bringing back pleasant memories about the Chinese executives and engineers we met and hope the suggestions and guidance given may enable them to carry on—but it must be remembered that we were there 100 days only and this, compared with the age of Chinese civilization, is not much!

The text of Tseng Yang-Fu's address follows:

ADDRESS BY TSENG YANG-FU

Mr. Chairman, Our American friends, and Gentlemen:

It is a well-known Confucius saying, "What a happiness to have friends come from afar!" When those who have come are with a mission to diffuse knowledge, to impart experience, and to enhance the strength of a nation in her struggle for existence, the happiness is far from being ordinary—it is a boon of historical and international significance. Real good friends are not many. Friends of this significance are still fewer. For this reason all of us feel it an unusual fortune of ours to have contracted the friendship of the technical experts who have come with the Nelson Mission.

Having successfully discharged the duties assigned to that mission, they are now going to leave us for the time being. On this occasion, it is with a united pleasure for the War Production Board of China, the Chinese Society of Engineers, the Chinese Society of Mining and Metallurgical Engineers, and the Chinese Society of Mechanical Engineers to give this party to our guests of honor, Mr. Graham, Mr. Strain, Mr. Ovesen, Mr. Waldschmidt, Mr. Bell, and Mr. Stalling, the steel, iron, coal and coke, and alcohol experts of the Nelson Mission. To you, my honorable guests, I am asked by the four bodies of hosts to address this short message of greetings.

First of all, we must thank you for the many improvements you have enabled us to make in our iron, steel, and alcohol production. You have acquainted us with better technics and thereby raised the quality of the output. Again, you have helped us tremendously in that, through your expert counsel, we have arrived at a co-ordinated plan of the steps, methods, and processes to increase our wartime production of these and many other kindred materials.

Compared with America, we are fully aware that our scale of production is very insignificant. This is particularly so after the enemy's occupation of a greater part of the country. In spite of these drawbacks, however, you have shown us what Chinese-American co-operation can do in amplifying the very little we have got. Although the production is still exceedingly small, it is to be borne in mind that a most desirable form of co-operation is thus begun. This is of paramount importance. America and China must co-operate in order to achieve a total victory. And again, they must co-operate in order to win the peace. And finally, the world requires their co-operation to go on uninterrupted that the peace so dearly won may hereafter be made to stay.

In spite of all other differences, it is singular to note that the two great peoples on the opposite sides of a great ocean have in them the same cardinal virtues of a peace-loving and non-aggressive type. When their freedom is violated, both will rise as one man to fight for their cause with a heroic aim. This oneness of virtues cannot bid any fairer to all the co-operations that are required of the two countries. Whatever differences there may be are only some remnants from the differences in the historical origins of the two civilizations. If carefully analyzed and impartially discerned, the two different cultures could well be correlated and used to supplement each other instead of being left to cause friction and misunderstanding which have become current between different peoples.

The West has derived most of its civilization from three sources. (1) Greek culture, (2) Hebrew religion and ethics, and (3) modern industrialism. From the Greeks it has derived its literature and arts, philosophy and mathematics. From the Hebrew it has derived its religion with the western conception of "sin," and from the nationalism of some of the European countries. From science, as applied to industrialism, it has derived power and wealth, and, when misdirected as by the Axis, the belief that they are as gods, and may take the life and property of the less scientific peoples.

None of these sources plays any part in the development of the Chinese civilization. The oldest teaching in the Chinese philosophy of life is perhaps traceable to Lao-Tse; that for moral conduct and etiquette is largely attributable to Confucius. About a thousand years later, that is, in the early centuries of the Christian era, teachings of Buddhism began to flow into China and were soon amalgamated into the teachings of the other two sages. Through all these centuries and from the combination of all the three kinds of teachings has emerged a civilization which is peculiarly China's own and which is oftentimes inexplicable to a westerner.

In short, our civilization is one of contemplative wisdom rather than mechanical efficiency. It is a culture for defensive tolerance, for modesty, for love of peace and freedom. It disdains offensive aggression and condemns the desire of dominance. All these characteristics are, however, not to be mistaken for weakness. In reality they are an actual source of strength in a form which is peculiar to the race. This is the strength by which we have conquered all our conquerors. This is the strength with which we have prevented Japan from realizing her imperialistic ambitions despite her military superiority. And this is the strength which has enabled us to persist while all the other nations of antiquity have long since perished.

China is much larger than the United States in area as well as in population. It contains within its territory many rich resources. It also contains, in the traits of the people and in the teachings of the ancients, a wealth of oriental wisdom. The former are awaiting the technical and economical co-operation of our national friends for their development. The latter is awaiting the unprejudiced and industrial co-operation of the same friends for their being turned into use for the benefit of the whole world.

Contacts between different civilizations have often in the past proved to be landmarks in human progress. Greece learned from Egypt, Rome from Greece, the Arabs from the Roman Empire, and Medieval Europe from the Arabs. In many cases, the pupils turned out better than their masters. In the case of China and America, both will find plenty to learn and both have plenty to teach. Through the successive steps of co-operation between the two countries, may we hope to see these two different civilizations rapidly merging into one to insure the one object of all mankind, that is, world democracy with permanent peace.

Under this light we feel it fitting not only to congratulate our guests of honor for the success in this mission to China but also to encourage and request them to take an active part in all future missions and occasions that will bring about a real union of the East and the West to the common good of all nations.

ATOMIC ENGINEERING?

By THEODORE VON KÁRMÁN

CALIFORNIA INSTITUTE OF TECHNOLOGY

IT has happened now for the third time in our lifetime ("our" referring to the elders of the engineering profession) that new avenues of engineering activities of tremendous importance have been opened by physicists and the engineering profession has found itself unprepared to challenge the task.

In 1887 the physicist Heinrich Hertz discovered "wireless telegraphy." In fact, he experimentally confirmed the existence of electromagnetic waves which anybody may easily read in Maxwell's equations of the electromagnetic field, i.e., anybody who can read equations at all. It took several decades for radio engineering to become a branch of the engineering profession and for adequate measures to be taken to incorporate the fundamentals of field theory into the engineering curriculum.

The discovery of electromagnetic waves of long wave length was followed very soon by the discovery of X rays, i.e., electromagnetic waves of very short length of a frequency far beyond the spectrum of visible light. It has to be said to the credit of the engineering profession that it took advantage of X-ray techniques in various industrial fields and the design and construction of X-ray apparatus was recognized as an important branch of engineering.

Similarly, the infrared technique, i.e., the technique of waves longer than those of visible light but very much shorter than radio waves, was justly considered as an engineering problem.

However, in the period between the two world wars, physicists made great efforts to narrow the gap between radio and infrared waves. They succeeded in producing microwaves which made possible the marvelous technique now commonly designated as the art of radar. The physical facts were known a long time before the beginning of the recent war. However, during the war, physicists, by their superior knowledge of electronics, i.e., the mechanics of electric particles, were able to solve the engineering problems of producing and directing microwaves. I will not contest the fact that a great many American engineers were sufficiently familiar with electronics; many made important discoveries and contributions to electronic devices. But somehow our engineering education does not encourage the idea of the unlimited horizon, when fundamental thinking in novel fields is required.

And now it seems we are at the threshold of the new atomic age. I do not know whether or not this is true, but certainly we shall have "atomic engineering" in the fields of power and transportation. Are we prepared for the problems involved?

The first application of atomic engineering was directed by military engineers; plants and many gadgets were probably designed and constructed by engineers. However, not only the discovery of the fundamental facts but also the methods of application were suggested, worked out, and tested by physicists. I concede that security regulations and personal relations in the "nuclear clan" played a great part in the choice of collaborators. However, I raise the question, do we give today to the future engineer enough fundamental knowledge in basic questions of the structure of matter, the nature of energy, the relation between matter and energy, so that he will be able to think intelligently in the new field, to have good engineering judgment on possibilities and methods? Is he better equipped than anybody else who reads a few popular articles in the *New York Times* or in the *Saturday Evening Post*? Is there something wrong in our engineering education? I am afraid there is.

First, I believe we have a tendency to restrict our teaching to scientific knowledge which has immediate applications. We often forget that almost every new physical or chemical discovery *might* have engineering application. After all, engineering is the conquest of nature, i.e., matter and energy, for human comfort, and therefore an engineer cannot know too much about the inner structure of the matter against whose whimsical moods he struggles and the laws of energy which he wants to exploit and harness.

Second, we underestimate the interest of our students in "natural philosophy." We are reluctant to present the fundamentals of physics and chemistry as a living science full of question marks and changing concepts. We believe we ought to introduce the findings of research only after the unshakable truth has been established. We tend to stick to classical concepts. I found while teaching mechanics of continuous media, elasticity and fluid dynamics, my students listened eagerly as I told them something about atomic structure of the materials and kinetic theory of gases. I wonder how many engineering students obtain a picture of entropy, chemical reaction, and the like, from a modern point of view. And why should ordinary combustion be an engineering topic, and nuclear reaction a mystery of modern alchemy?

Third, we overestimate the importance of transfer of experience to coming engineering generations in comparison with a training aimed at true understanding of the happenings of nature. We try to train engineers so that the employer can use them almost immediately after graduation from school. One of my former students was employed as an instructor in a well-known engineering school. He suggested some changes in the hydraulics curriculum in the direction of modern fluid dynamics. His superior asked him the use of teaching the findings of research men who, he conceded, found interesting results in hydrodynamics. None of these men, he said, would be able to design a sewage pipe system. No doubt he was right in this statement of fact, but he was wrong in his conclusion. Fortunately, the more intelligent employers are beginning to realize that immediate usefulness is not the most important criterion of a novice engineer. They appreciate sound fundamental understanding and do not want the school to train for them the type of practical engineer, who—according to the *bon mot* of a prominent Englishman, himself an engineer—perpetuates the errors of his predecessors.

Fourth, I certainly do not wish to make of every engineer a scientist, or, God forbid, a nuclear physicist. However, we shall try to give him an education which shall enable him to follow the progress of science, as, I believe, every medical doctor should have sufficient education, to follow the development of biology which has produced in our time almost as spectacular discoveries as physical science. At the institution at which I have been teaching in the last fifteen years, science and engineering students have essentially common curricula the first two years. The physics student continues after that to move on a relatively high intellectual level of understanding natural phenomena from a scientific point of view. I have often wondered why the engineering student has to make a steep dive into an atmosphere in which the beam on three supports is considered a most difficult problem and the exact clear principles of mechanics and thermodynamics are replaced by semiscientific, semipopular "ersatz" truths.

I am convinced that the knowledge of the deepest origins and also the limitations of the principles does not handicap a

(*Continued on page 679*)

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

Reincarnation

DURING the war this department, familiarly known as the Record, was regretfully abandoned because of limitations of manpower and paper. For several years prior to Pearl Harbor the major responsibility for providing material for the Record had been delegated to Leslie F. Zsuffa, then on the A.S.M.E. editorial staff. When he entered active military service the Record fell to the lot of others until W.P.B. limitations on the use of paper, coupled with an increase in A.S.M.E. meeting activities and in technical papers, called for curtailment somewhere along the line. The Record fell under the axe because its going eased both the manpower and the paper shortages.

The Record was not without friends who mourned its passing and prayed for a reincarnation. These evidences of esteem were flattering to the editors and brought forth promises that the department would be re-established as soon as paper limitations were removed and editorial staff should become available. Late in August the paper limitations were removed; and although no additions to the staff have as yet been made, the promises are to be redeemed. Acting therefore on President Cleveland's advice that the way to resume is to resume, the Committee on Publications has decided to wait no longer. Its plans for improvement of MECHANICAL ENGINEERING, laid many years ago in anticipation of peace and the removal of wartime restrictions, gave high priority to re-establishment of the Record. Indeed, the A.S.M.E. Group Delegates Conference, meeting in Chicago in June, 1945, urged early resumption of this service. With this issue and under certain handicaps, reincarnation of the Record becomes a fact.

Change

LESLIE ZSUFFA was commissioned as a reserve officer when he was graduated from New York University where he had been a member of the R.O.T.C. During the years that intervened between his graduation and the outbreak of the war in Europe he spent his summer vacations at military training camps and was advanced to a first lieutenancy. Before Pearl Harbor he was called into active service in the Quartermaster Corps, later transferring to the Transportation Corps, and was stationed at Governor's Island, N. Y. A bewildering assortment of assignments tested his engineering and administrative skill. When an opportunity arose to attend the military government school at Charlottesville he accepted it. Shortly after graduation from this school he was sent to England and later followed the invasion forces into Europe. When he returned to this country he was a lieutenant colonel.

Zsuffa cut his journalistic teeth by reporting the news of the A.S.M.E. Student Branches. He was one of a group of junior members of the A.S.M.E. Metropolitan Section who took over the task of getting out a special bulletin for the Student Branches when other plans for stimulating the interest of this important body of young engineers had been found to be unsatisfactory. With him served L. N. Rowley, who will be chairman of the Committee on Publications during the administrative year of 1946, and O. B. Schier, 2nd, now serving in the Navy, who is an advisory member of the Committee.

Zsuffa exhibited a flair for publicity and the abstracting of technical articles. He joined the editorial staff of the Society and became an enthusiastic and indefatigable worker. Wishing to enliven his reports of society meetings with "candid shots" and failing in his attempt to persuade the Society to buy him a camera, he purchased a small boxlike affair for less than five dollars and got several hundred dollars' worth of pictures with it. Members who attended meetings in those years will remember how he would slip into a meeting room, mount a chair or couch in some strategic lair, and take flashlight pictures of speakers and audience like any hardened cameraman. It was hard to discourage him when he set his mind to a task. A night-school course in public relations had convinced him of the value of publicity and taught him the techniques of handling it. It was natural therefore that he should assign himself the task of publicizing A.S.M.E. activities. On many occasions he picked his own subject, gathered material and wrote his story, cut the stencils, mimeographed the releases, and put them in envelopes for mailing. At meetings he called on the city editors and introduced himself and ran a pressroom. He called reporters and cameramen by their first names, gave them service, introduced them to the important speakers, provided handouts and manuscripts of papers, told them what was important, and provided background material. His engaging personality and his tireless energy paid dividends with the press.

Although Zsuffa's colleagues hoped for his return to the staff at the end of the war, they recognized that his talents would probably open up for him opportunities he could not afford to reject. This has now happened. Zsuffa returns to civil life to fill an important post in the field of public relations. Great regret is felt that he leaves his position on the A.S.M.E. staff. The best wishes of his friends and colleagues go with him in his new job.

Paper

ALTHOUGH the W.P.B. limitations on the use of paper were promptly removed in August, several months must elapse before publishers will find stocks available in quantity and quality to meet all their needs. After months of cheeseparing economies in the use of paper it will be a relief to publishers and readers alike to return to former standards of quality and appearance. By the first of the year, pages should be whiter, illustrations clearer, and the reader should no longer be confused by seeing the printing on both sides of the sheet at the same time. When printing was at its most discouraging low ebb during the war, the editors of MECHANICAL ENGINEERING frequently took down bound copies printed in peacetime and wondered why it was ever necessary to rebuke the printer for muddy cuts. Printers take pride in their work too, and what could they do with such paper? So the problem would be taken to the Committee on Publications with a request to spend more money for better paper. The shrewd but tactful members of the Committee usually expressed amazement; the cuts were beautiful, the printing clear! After all, they were publishing a technical magazine, not *Vogue*. They could not justify the expense of better paper. Today every one is tired of poor paper and noting improvements in appearance that will come with better paper is going to be a pleasant experience.

Grist

DURING the war years the flow of interesting material over the editor's desk could not be diverted to the Record. Many luncheons were attended but there was no opportunity to comment on the new subjects discussed on these occasions. Pamphlets and magazines were stacked up to gather dust and eventually to be sent to the library. There was grist for the mill but the wheels of the mill were stopped. When the unexpected occasion came in August for renewing the Record, material that had lingered on the desk for the last few weeks was available with which to make a start. Even the heat was no excuse for further delay.

Atoms

WHEN the curtain of secrecy was raised on the two billion dollar research project that resulted in the atomic bomb, it became evident through the press and publicity releases that almost everyone had had a finger in it. Of the many stories built up around the splitting of the atom two of the most readable appeared in the August 18 issue of the *New Yorker*. One was a full-length "profile" of William L. Laurence, science reporter of the *New York Times*, who has been a well-known figure at A.S.M.E. Annual Meetings for several years. Laurence has an uncanny faculty for picking out the significant kernels of useful facts from the chaff of technical details that confuse the average reporter—and frequently the average engineer too. Other reporters group themselves around him in the pressroom while he thumbs over the handouts and wait for him to light on the paper that he knows has a story in it. "Now this is your lead for this article," he says, and then proceeds to tell them what it is. One evening years ago he gave a thoroughgoing lacing to an eminent dean who had failed to deliver the lecture he had sent out in advance. There was a full-column story on the presses for the first edition of the next morning's *Times* which Laurence had to kill by telephone. By the time the second story, based on what the lecturer actually said, was written, it made only the late city edition and the dean lost his nation-wide publicity. But Laurence wrote the second story.

In the *New Yorker's* "profile" much well-deserved credit is given Laurence for bringing to newspaper readers intelligible stories of what scientists are doing. Among these stories are many which Laurence has written since 1940 about atom smashing, beginning with an article in the May 5, 1940, issue of the *Times* in connection with experiments then being carried on at Columbia University. What was going on at Columbia is reported elsewhere in the *New Yorker* under the caption "Fateful Night" and tells how Dr. John R. Dunning and Dr. Enrico Fermi, by means of the cyclotron, had amazed themselves by releasing atomic energy.

Reading the *New Yorker* recalls many incidents of these early days. It recalls a dinner at which Dr. Gano Dunn, with ill-concealed excitement, explained the new discoveries at Columbia and speculated on their significance. It recalls a visit to the Pupin Physics Laboratory where Dr. Dunning gave a demonstration of the transmutation of metals to two inquiring engineers. It recalls a remarkable demonstration lecture in the auditorium of the Engineering Societies Building under the auspices of the American Institute of Electrical Engineers in which Dr. Dunning and Dr. Fermi amazed a large audience with reports of their work. Dr. Fermi's lecture, "Nuclear Disintegrations," appeared in MECHANICAL ENGINEERING for February, 1940, a brief but prophetic preview of things to come.

A great deal of concern has been expressed over the fact that this most extraordinary development of science, the release of atomic energy, should have been used for destructive purposes in the bombing of two Japanese cities. Many persons apparently believe that scientists had purposely devoted their talents to the development of new means of destruction. Although the atomic bomb was the first large-scale use to which atomic energy was put, the bomb itself was a by-product of scientific advancement. Such has ever been the history of new weapons of war—their origin has been inspired in the search for useful knowledge and the development of the arts of peace. The airplane and nitroglycerine serve as two well-known examples.

If the scientists who developed atom-smashing in this country had in their minds the use of the technique for military purposes, they said little or nothing about it. One recalls that the group at Columbia talked of little but aids to biological research and medicine. Indeed, Dr. Fermi concluded his lecture by saying: "The large release of energy by the reaction whose development, by the way, could be easily controlled by simple mechanical devices, is indeed only one and very likely not the

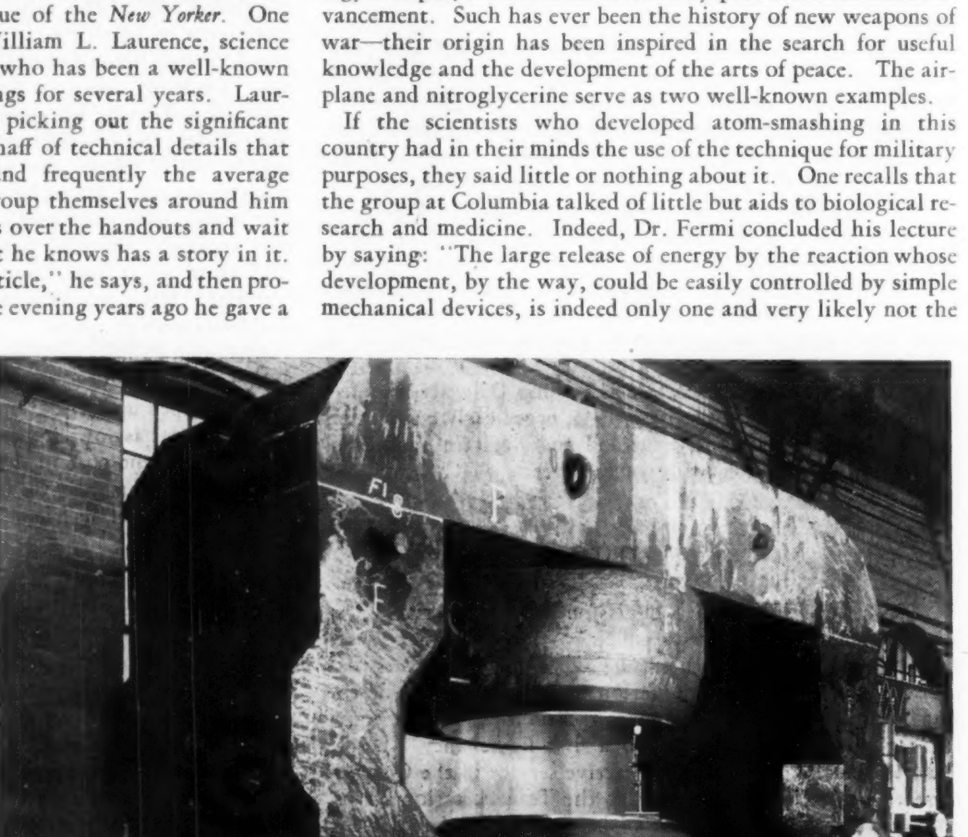


FIG. 1 ENGINEERING AIDS ATOM SMASHING

(Cyclotron magnet for Carnegie Institute of Washington. Photograph shows surfaces and adjustment of the pole faces being checked in the shops of the Mosler Safe Company, where the magnet was machined, before shipment to Carnegie Institute. The magnet was cast by the American Rolling Mills.)

most important aspect of the problem. Far more important might eventually prove the production of radioactive materials and of neutrons in practically unlimited amounts, for medical, biological, and physical investigations. In conclusion, therefore, although there is only a chance of success on these lines, the stake appears large enough to justify some gambling on the part of scientists."

Editorial comment in Mechanical Engineering on Dr. Fermi's lecture stated: "What the researches about which Dr. Fermi writes will ultimately mean to engineers and to the world in general, the scientists engaged in making them are too cautious to predict. We do know, however, that they have demonstrated the possibility of transforming matter into energy and of changing one material into another.... What is startling about the recent discoveries .... is that a self-generating chain reaction has been found from which one might hope to expect the release of energy in amounts greater than those necessary to break the nucleus apart, and that the new substance is radically different from that from which it came.... Hence one ventures to predict that the cyclotron .... will become one of the most significant tools of science and that the discoveries it makes possible may profoundly affect engineering practice."

Later in the year, June, 1940, editorial comment became bolder. "To each man, according to his nature and the inspiration of his imagination, the work of scientists with the cyclotron in the attack on the atomic nucleus will have its own meaning. Some will see in the progress of these investigations the development of new techniques of biological study and medical science. To others the tremendous destructive force that would accompany the violent disintegration of the nucleus will suggest a new weapon of offensive warfare. Engineers will be interested in the controlled release of energy for useful purposes—a new source of power.... In the present mad mood of the world it is fortunate that the progress of science is relatively slow."

During the dark years of the war when threats of secret weapons were frequent, it was pondering on these speculations that caused the writer of those words many sleepless hours. From the club and stone to the atomic bomb there are no humane weapons of war. As men's knowledge has progressed man's power of destruction has increased but so also has his power to perform constructive tasks. The development of atomic energy will be no exception.

To footnote these comments on the atomic bomb reference is made to two dispatches to the *Times* from Bill Laurence "with the Atomic Bomb Mission to Japan." The first, dated August 9 but delayed and published on September 9, is the story of the flight during which Nagasaki was bombed—a piece of reporting which should win the Pulitzer Prize had not Laurence already been so honored. The second, dated September 9, Nagasaki, Japan, one month after the bombing and published on September 10, tells of the havoc wrought as seen from the ground.

Cyclotractors

A writer in *The Economist*, August 11, calls for the "mobilization of muscle" in the face of the extraordinary conditions that exist in the world as a result of the war. Stating that there is a world famine in coal, fats, rolling stock, and other goods he asserts that "it is generally assumed that the key to this situation is transport. This," he argues, "is an inadequate and, perhaps, dangerous analysis; for the shortages function reciprocally. Transport cannot function without (1) coal or other power, (2) equipment, and (3) labor. Coal cannot be produced . . . without food. Food cannot be produced without coal or its equivalent power. A ton of refined sugar, for example . . . needs a ton of coal for its extraction." We have grown up, he asserts, in the illusion that the world was rich in power. "In truth, both the world as a whole and Europe are wretchedly poor in power."

Of four significant sources of power in the world, coal, oil, hydroelectric, and muscle, *The Economist's* correspondent deals with the last named. "Muscle," he says, "is not a source of power but a chemical engine using the molecular energy of food-fuel." Because "the body is a singularly efficient engine," he argues that energy used as food will produce twice as much work as the same amount of energy fed to a steam locomotive. In a diagram of the comparative results of two methods of using coal he shows that one pound of coal used to make beet sugar fed to a worker will be converted into 364 calories of work output with an over-all efficiency of 11.5 per cent, while the same pound of coal utilized in a steam locomotive will result in a work output of only 173 calories. Why not, then, use the coal to produce food energy in the form of sugar instead of feeding it to locomotives?

How will muscle take the place of the locomotive? Clearly worth considering, he asserts, are cyclotractors, "bicycle-type structures, though with four wheels, seating 20–30 men, to get moving on railway and road every mobile vehicle from those of least resistance, such as goods wagons, down to carts, pending the production of further and perhaps more appropriate vehicles. With such cyclotractors on railway tracks," he estimates, "men exerting one eighth of a horsepower each could move 45 gross ton-miles (30 ton-miles of freight) a head in an eight-hour day, assuming the wagon to be always fully loaded."

"It will now be clear," this correspondent aserts, "how inadequate and dangerous has been the analysis which defined transport instead of power as the basic factor in the present situation. For . . . if all Europe's prewar rolling stock and more were available, so long as there are starving populations, so long, for example, as all Europe's sugar beets could not be made into sugar for want of coal, as is now the case, it would be more economic, and politically necessary, to eschew the use of coal for engines whose over-all efficiencies were less than about 11.5 per cent, and to use it instead to make food such as sugar. Half of the sugar—given the appropriate equipment—would be needed for the haulers taking the place of the steam engines, but the other half would be available to feed other workers, such as coal miners, whose present output is so heavily reduced for want of food."

As to the coal equivalent of workers the correspondent estimates, "the coal value of the 5,000,000 prisoners in Allied hands (stimulated by appropriate rewards) and of seven million out of all Europe's population would alone be about 12 million tons of coal a year. The steel needed for the cyclo-tractors for this number of haulers would amount to 110,000 tons."

The scheme is not proposed as a permanent arrangement. "In Western Europe it would be a two or three-year substitute for unmined coal."

Duodecimals

An editorial in the August issue of Mechanical Engineering called attention to Walter R. Ingalls' recent pamphlet and reviewed some A.S.M.E. papers and discussions on the metric system over a long period of time. Among the authors quoted was George Wetmore Colles, whose A.S.M.E. membership dates back to 1895 and who resides now in Texas in a place having the romantic and euphonious name of Rosharon. Mr. Colles must still read Mechanical Engineering for he wrote to the editor about the editorial, chided him in a kindly manner for not mentioning the duodecimal system, and called attention to The Duodecimal Society of America, with headquarters at 20 Carlton Place, Staten Island, N. Y. The letter will be found in the regular department devoted to correspondence and comments in this or some later issue.

Shortly thereafter came Ralph H. Beard, secretary and

treasurer of The Duodecimal Society of America, to call on the editor and to leave with him a leaflet describing the society and a copy of the society's publication *The Duodecimal Bulletin*. The principal feature of the society's emblem is what appears to be a clock face without hands. It looks familiar until one reaches 10 o'clock. There the 10 is replaced by *X* and this is followed by a substitute for 11, which is the numeral three standing on its head, and a zero where 12 should be. The other difference is the six, rather than five, subdivisions between each digit. Around the outside of the "clock face" runs the society's name.

Undoubtedly a majority of engineers have amused themselves from time to time with systems of arithmetic based on other than ten digits. You can start with, say, three digits, which is rather silly, and go to as many as you please, which gets to be absurd. But if you stop at 12 you have the duodecimal system. Systems with fewer than 10 digits are easiest to begin with because you don't have to invent new numerals or names for them. You just throw out the numerals you don't need. But you must be careful when you come to two-digit numbers, because, in every system but the one we are all familiar with, 35, for example, is no longer thirty five. An ingenious person who grasps the principle of the thing has little trouble in the early stages of a new arithmetic.

Everyone knows, who stops to think about it, that we owe our present system of numbers to the fact that man began counting on his fingers, of which there are normally ten. If we had evolved with twelve fingers instead of ten we would all be using the duodecimal system today and The Duodecimal Society of America would never have been formed.

What appeals to the average person about the "metric" or French system of measures is not that they prefer meters to yards, decimeters to feet, and centimeters to inches, but the convenience of decimals as compared to fractions. They prefer United States money with its dollars and cents to the British with its pounds, shillings, and pence.

The June, 1945, issue of *The Duodecimal Bulletin* contains a brief article by Mr. Beard, "The Do-Metric System, a Dozenal System of Weights and Measures," from which the following is quoted:

"A world standard of weights and measures is necessary. This standard should constitute a unified metric system, whose units are convenient in practical use, whose scales accommodate ready subdivision into halves, thirds, and quarters, and whose components are precisely integrated. None of the present official standards meets these requirements. None shows any real promise of becoming the world's standard. Yet there is a fully adequate solution to this problem.

"Today there is a growing interest in the use of base twelve in numeration. It is generally recognized that counting by dozens offers many advantages over counting by tens. It is to be expected that the change from tens to twelves may take a long time, but, since the dozen base is better, ultimately the change is inevitable.

"With this change, then, there is available to us a unified metric system whose units are accustomed, convenient, and practical in size, whose scale facilitates easy subdivision, and whose elements are precisely integrated. This duodecimal metric system, termed 'The Do-Metric System,' offers excellent potentialities for adoption as the world standard."

One way to popularize the duodecimal system would be to introduce it into the schools. A few exercises based on this system would teach children a lot about arithmetic and sow seed in fertile soil.

PMH

THE significance of production per man-hour, PMH as *The Economist* abbreviates it, is being drilled into the consciousness of the British by that weekly periodical and by the reports on some of Britain's industries that reveal production rates generally lower than the best attained in this country. Important to any industrialized economy at any time, high productivity is especially important today for a world in which disorganization of industry, destruction of much production capacity, disruption of transportation, and possible starvation and anarchy threaten many areas. And while not all of these dire calamities threaten Great Britain, the tasks of reconstruction and reconversion and the recapture of lost markets are further complicated by a program of nationalization of certain basic industries which the new Labor government is pledged to put into effect. Timely, therefore, is the article, a warning of stark realities, in *The Economist* for August 4, 1945, "Nat and Rat," or nationalization and rationalization, "The greatest need of the country," asserts *The Economist*, "is not for Nationalization but for Rationalization, for a far-reaching re-examination and overhaul of the whole mechanism of production and exchange."

"An hour of work in Great Britain," asserts *The Economist*, "produces less in material product, relatively to other countries, than it used to, and less than it will have to if the British people are to keep their place among those with high standards of living. Now that the country is no longer a creditor nation, it will no longer be possible to have European standards of production and American standards of living. Either the one must come up or the other must come down. And if it is to be the standard of production that is raised, the effort necessary will affect every department of the national economic life. No one section of the people is wholly to blame for the state of affairs that has arisen. The average standard of business management is low; but part of the blame rests on government which has imposed crushing taxation without sufficient thought for its effects; and part rests also on a trade union movement which has encouraged the belief that more income can be got for less output. By the same token, every section of the nation will have to make its contribution if the compaign for national wealth is to succeed.

It cannot be sufficiently insisted that this is the basic economic problem of the British economy. The nation's resources have been pledged—in social security at home and in financial debts and political commitments overseas—to a degree which cannot be supported unless there is a rapid and sustained increase in its wealth-creating capacity. On this all else turns, and if the campaign for national wealth fails, all other plans, economic, social, and political, will turn to ashes. The greatest need of the country is not for Nationalization but for Rationalization, for a far-reaching re-examination and overhaul of the whole mechanism of production and exchange."

Engineers will understand this philosophy. The purpose of quoting these sentences is not to thank God with the Pharisee that we are not as other men are but as a warning and in the humble spirit of the publican who smote his breast, saying, "God be merciful to me a sinner." For economic advantages are not permanent if men thoughtlessly let them slip from their grasp.

Management

ASKED to prepare a list of books on management to be circulated in Latin-American countries by the Office of the Co-Ordinator of Inter-American Relations, Harry Arthur Hopf, member A.S.M.E., attempted to meet the original specifications set for him by the Pan-American Committee of the Society for the Advancement of Management of a list of twelve "must" books and twenty "recommended" books. The lists as finally compiled by Mr. Hopf, however, ultimately contained 50 titles and have been published by him in a pamphlet, "Soundings in the Literature of Management, Fifty Books the Educated Practitioner Should Know."

The fifty books are divided into three lists. The first, "Readings in Scientific Management," contains 12 titles, preceded by Mr. Hopf's brief comment. "Twelve Indispensable Works" make up the second list. Under each title are brief comments. The third list of 24 recommended works provides, Mr. Hopf says, "a thoroughly adequate foundation for the acquisition of a comprehensive knowledge of the substance of management."

In a concluding comment Mr. Hopf states that "the guiding principle adhered to in doing justice to the problem of selection was to favor, wherever possible, works that would contribute to enlargement of the reader's intellectual horizon. . . . . In management we need more educated men and fewer specialists. We need far more the capacity to think in terms of fundamentals than the ability to be facile in the use of instruments of precision. We need more philosophers with a spirit of inquiry dominated by broad perspective and fewer technicians whose customary approach only too often narrows down to a point. Above all we need men whose intellectual equipment will enable them to accept and to act upon the implications of the optimum."

If the fifty books in Mr. Hopf's list will assist in the development of managers of the type he advocates, the schools in which engineering students receive their first instruction in this important field should set these books apart where they are readily available and contrive ways to get young men to read them.

Gas Turbines

ON July 25 the Elliott Company at Jeannette, Pa., operated for the benefit of a group of editors of technical magazines the 2500-hp gas turbine which it has developed with the U. S. Navy, Bureau of Ships, for ship propulsion. In connection with the demonstration a number of engineers discussed a variety of phases of the new power unit, among them C. Richard Soderberg, member A.S.M.E., who compared the gas-turbine unit with other more usual types of prime movers. He said in part:

"The Elliott development was focused, from the start, upon a gas-turbine plant which would be able to take its place among the existing prime movers with respect to fuel consumption, partial load and maneuvering characteristics, reliability, weight, and space requirements. Another important consideration, unique in this particular development, was the adoption of a positive-displacement compressor, whereby surging phenomena would be completely eliminated. In respect to the first two of these considerations this particular development has unique significance. The advantages to be obtained by subdivision of the plant were adequately explored for the first time, and it is a testimony to the foresight of the U. S. Navy and to the Elliott Company that a plant of this type was decided upon, rather than the simpler arrangements. This decision also made it possible to reach high efficiency with conservative maximum temperatures. The result is a prime mover which falls into the class of Diesel engines with respect to fuel consumption, but which should approach the steam-turbine plant in reliability and maintenance. With respect to weight and space requirements, it should be superior to both. It should be kept in mind, however, that in these latter respects experience will have to be the final judge, and considerable development may be expected in such matters as compactness of layout, accessibility, and so on.

"This plant has an over-all efficiency of about 29 per cent which is probably capable of extension to 31 per cent by modification of details, but without change of basic premises. This falls in the range between approximately 26 per cent, which may be looked upon as the practical limit of a small up-to-date steam plant, and 33 per cent, which is the corresponding limit for an up-to-date Diesel engine. The partial-load characteristics are subject to considerable variation in all prime movers, depending on the degree of complication which is accepted. It may be stated, however, that in this respect the present type of gas-turbine plant will compete successfully with either the steam plant or the Diesel engine.

FIG. 2 LYSHOLM COMPRESSOR USED WITH ELLIOTT GAS TURBINE, UPPER PORTION OF CASING REMOVED

"So far, no fully satisfactory solution has been found to the problem of reversing the direction of rotation of the gas turbine, and in this respect it is at a disadvantage compared to the other two prime movers, where reversing is practical without excessive complication. The reversing problem must be solved in connection with the drive arrangement.

"The weight of the present plant is approximately 30 lb per horsepower and it occupies a space of approximately $3^1/_2$ cu ft per horsepower. It is our belief that these figures are capable of considerable improvement, particularly the space per horsepower, which we know will be reduced to less than two cubic feet per horsepower in subsequent Elliott gas-turbine plants. It is too early to make definite statements with regard to the cost of gas turbines, but it seems probable that when the designs have become stabi-

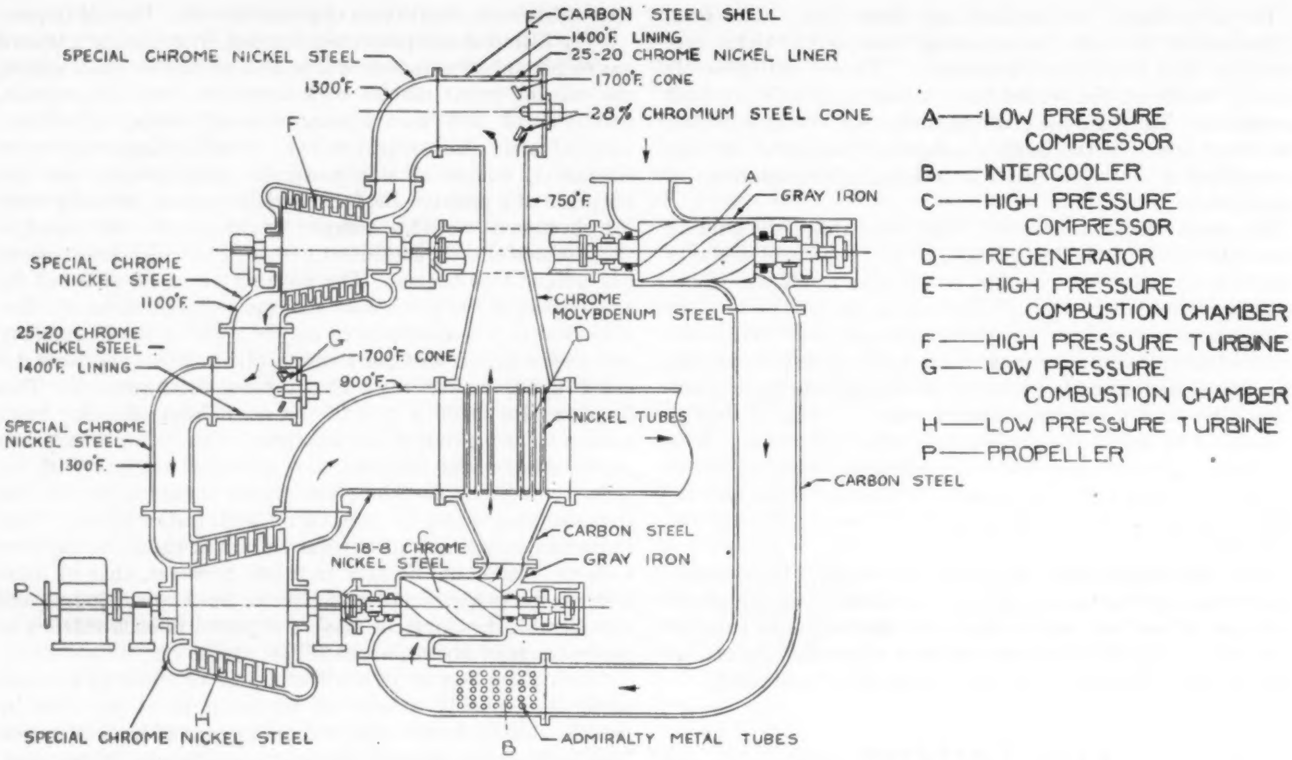


FIG. 3 SCHEMATIC OUTLINE OF ELLIOTT GAS TURBINE SHOWING MATERIALS USED AND TEMPERATURES EXPERIENCED IN VARIOUS PORTIONS OF THE UNIT

lized in conjunction with suitable manufacturing facilities, the cost will be less than that of steam plants but probably of the same order as the cost of Diesel engines.

"These generalizations of the probable characteristics of the gas turbine in relation to other prime movers should not be considered in too literal a sense, because all of these figures fluctuate with the size range involved. The steam plant is outstanding in that there is practically no limit to the size of individual units that can be built. In contrast with this, the Diesel engine is rather sharply limited, although the exact figure varies with different manufacturers. At the present moment the gas turbine is capable of construction in sizes somewhat above the largest Diesel engines. It is generally agreed that this limitation is of a somewhat temporary nature, and plants of the order of 10,000 to 15,000 hp are certainly possible. Given the necessary incentive, this limit may be pushed much higher, but it is probable that units in the size ranges common in the central-station field will be some time in coming.

"The present plant is designed to burn high-grade fuel oil, but no serious difficulties are expected with lower grades and eventually Bunker C may prove practical. When this step has been reached the gas turbine will have an important advantage in comparison with the Diesel engine, and it will be on a par with the steam plant for the majority of transportation applications. However, the burning of coal instead of oil will always be an important consideration, and the field of the gas turbine will be vastly extended when this possibility is realized. Many approaches to this problem are already under investigation, and practical solutions are certain to be forthcoming eventually. Whether the ultimate solution will be direct burning of pulverized coal, burning of gas from coal, or burning of oil from coal is still in the future."

In connection with the temperatures that are encountered in various parts of the gas-turbine unit and the materials used, Fig. 3 will be found to be enlightening.

Ronald B. Smith, engineering vice-president of the Elliott Company, is a member of A.S.M.E.

Jets

UP to the time this was written only meager details were available of the turbo-jet engines built by the General Electric Company to power the Lockheed "Shooting Star," said to be the world's fastest airplane. At a luncheon held at the Waldorf-Astoria in New York on July 31 a group of editorial writers were privileged to see two of these engines from which a quarter section had been removed to reveal the interior. The single shaft carries, at its rear end, a gas-turbine rotor and at its forward end a compressor impeller. An extension of this shaft drives the auxiliaries (starting motor, generator, fuel pump, etc.) that are grouped at the forward end of the unit. Surrounding the gas-turbine unit are ten stovepipe-looking contraptions that are the combustion chambers, supplied with fuel by the fuel pump and with combustion air by the compressor. The products of combustion are expanded in the turbine rotor and pass into a cone at the rear of the engine, emerging at high velocity as a jet to propel the airplane.

Military jet-propulsion engines of various sizes, the largest said to generate as much power as the largest piston aircraft engine, were demonstrated on test stands recently at the Westinghouse Electric Corporation's Aviation Gas Turbine Division, South Philadelphia, Pa. It was announced that as soon as military demand would permit, a part of the company's manufacturing facilities would be turned to the production of commercial versions of the present jet engines. These postwar designs, however, will have propellers driven by compact lightweight gas turbines somewhat similar to those that now produce jet thrust. All the engines demonstrated were of the axial-flow type, with compressor and turbine on a common shaft, permitting small engine diameters for the power output. This design, it is said, should permit fitting of engines wholly within the wings of the airplane.

At Wright Field, Ohio, the Air Technical Service Command has been testing the first ME 262A-1 jet-propelled fighter captured intact by the A.A.F. It is reported that the main difference between the German jet planes' power plant and the

General Electric jet engines is that the former utilizes an axial-flow compressor instead of a centrifugal compressor. The German plane is powered by two jet engines, one mounted in each wing, while our jet fighters have the power plant in the fuselage. The German jet engine is a Jumo 004.

From the Society of British Aircraft Constructors, Ltd., comes some newly released details of the Gloster *Meteor*, Britain's first operational jet-propelled fighter, a twin-engined, low-wing all-metal monoplane with a nose wheel undercarriage. A high-set split tail plane is necessary to give ample clearance for the jets from the gas-turbine engines. The gas-turbine propulsion units are built by Rolls-Royce in collaboration with Power Jets Ltd., British Thomson Houston, and the Rover Company. It is said that at least two other gas-turbine engines are being developed in Great Britain, one by de Havilland (the *Goblin*) and the other, as yet unnamed, by the Bristol company.

Youth

IN concluding his remarks to the press at a luncheon at The Waldorf-Astoria in New York when the General Electric jet engine was "unveiled," R. G. Standerwick, engineer, Aircraft Gas-Turbine-Engineering Division, General Electric Company, paid a tribute to youth that is worth recording. Said he:

"To those of us who have spent most of our lives in the engineering profession, it is extremely gratifying to see the interest and productivity of the new generation of engineers in this work. It has been said that 'flying is a young people's sport.' Not so exclusively, please; aviation engineering is decidedly a young engineer's avocation. Youth, in the eyes of age, may be reckless, but youth is really agnostic and this shows up in engineering as well as in other activities. However, do not misunderstand me. Engineering youth is also trained to use sound judgment. Often, though lacking (and I say this facetiously) years of experience, they can accomplish in this day and age things which in our day were termed impossible. Upon this combination of a new art and well-trained youth I base my belief that progress at a high rate is inevitable."

Creative Engineering and Patents

(*Continued from page 634*)

The Commission has recommended that there should be a central body, in the Executive Office of the President, to supervise and approve departmental patent policies regarding employee inventions and the disposal of patent rights, and to instruct and advise departments and agencies regarding their patent problems.

MORE INVENTORS AND A SOUND PATENT SYSTEM NECESSARY

Science and engineering have demonstrated their value in supplying the type of knowledge needed to wage a modern war. To maintain our place in a warlike world we must keep our scientific and our engineering knowledge at a high level as a basis of national defense. We must continue research in war equipment and we must maintain an active armament industry as insurance for the future. At the same time we must have more men and women who have the ability to invent and develop new machines and processes useful in providing full employment and high standards of living for our people. For our country to grow and prosper we must have more epoch-making inventions fully protected by a sound patent system. For our war industries to be utilized most effectively in providing full employment we must have more new knowledge. For new wealth to replace the material losses the world has suffered in this war we must create new wealth through research and invention.

Evaluating Ball- and Roller-Bearing Greases in Electric Motors

(*Continued from page 646*)

sistency and a flow point of 332 F. This was put in the test motor and run for 18 days, during 4 of which the temperature on the bearing on the coupling end of the motor was 175 F and on the opposite end was 158 F. At the end of this time, the grease became so thin that most of it leaked out of the housing along the shaft and into the windings. That which was left was very soft and plastered around the balls. This grease was unsuitable as it would leave the bearing almost empty of grease after a few days.

Grease B. A ball-bearing grease of about 318 worked consistency and a flow point of 275 F. This grease was run at room temperature in the motor, then the temperature was raised to 175 F and held there for a few hours. The bearing temperature suddenly shot up to 284 F and stayed there for 2 hr when the motor was shut down. The test was repeated when the same thing happened, and it was decided that this grease would not stand 175 F without breaking down. The grease became very soft but did not leak out, remaining in the bearings.

Grease C. A ball-bearing grease of about 274 worked consistency and a flow point of 444 F. This grease was run for 3 weeks in the motor, 2 weeks at 90 C, and 1 week at 100 C. At the end of that time, its condition was perfect in appearance and it seemed to be operating very satisfactorily. Although it was quite stiff in consistency when cold, after this run, the consistency at operating temperature was very good and the bearing surfaces had a thin film of grease. In the author's opinion this grease showed good promise for further field trial.

Atomic Engineering?

(*Continued from page 672*)

person in their practical application; as a matter of fact, real knowledge makes the application easier and safer. And after all, physics students are not any more intelligent than engineering students.

I have digressed from the subject indicated by the title. From the little I know and the little I have read on the subject, I really believe that the problems involved in the development of atomic power for stationary and transportation purposes are primarily of the nature of engineering and especially applied mechanics. In other words, the picture of the nuclear processes obtained by the physicists contains so much of the truth, if such thing as truth exists, that from now on systematic observation and computation must lead to practical solutions. Certainly intriguing engineering problems, like the development of materials resistant to extreme temperatures and extreme corrosion, and difficult applications of our knowledge in diffusion and heat transfer, will be involved. However, it may sound paradoxical, but it seems to me that the processes involved in atomic engineering are less complex than, for example, the processes of combustion of conventional solid and liquid fuels; less complex in the sense that simple considerations and theoretical computations may give closer approximations to reality than in the case of molecular reactions. What can appeal more to a scientific engineer?

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Welding Engineering Must Be Based on Exact Science

Referring to page 136 of the February, 1945, issue of Mechanical Engineering, E. Paul DeGarmo, in reply to a letter[1] by J. F. Lincoln, cites a test specimen indicating initial failure of the specimen in the weld. It is our contention that citing this specimen actually supports the contention of Mr. Lincoln that science as applied to welding is not always exact science.

In the outset, it should be stated that we fully agree with Professor DeGarmo's closing sentence, "Welding as well as engineering should be an exact science." However, we would prefer to say: "Welding engineering should be an exact science," by which we mean to apply common engineering principles to welding design.

In citing this test specimen, exact science has not been employed for the following reasons. The specimen itself does not conform to good welding design for bending, especially if it is tested to destruction. It is not a design recommended for use in any kind of a welded construction because the specimen has been specially designed to cause the weld to fracture. For what other reason would the weld have been notched?

The writer is well acquainted with the work of H. E. Kennedy, by whose courtesy the specimen is mentioned, whose purpose was to prove that at extreme low temperatures welds will fail if subjected to notch effect, even while not under the influence of fatigue stresses, contrary to the general understanding that notch effect is of only minor importance for static loading conditions.

In citing this specimen a wrong impression that welds are not to be trusted is created for younger engineers not acquainted with the fundamentals of welded designs, instead of making it clear that failure is due to faulty welding design, permitting stress concentration and notch effect. In order to counteract this impression, an attempt will here be made to analyze this particular specimen and show why it is contrary to good welding-design practice and on the other hand why the test specimen is a typical example of a faulty unscientific welding design.

It is well known that the addition of a welding bead on top of a plate creates a stress concentration in bending. If the bead is assumed to be $^1/_2$ in. wide and

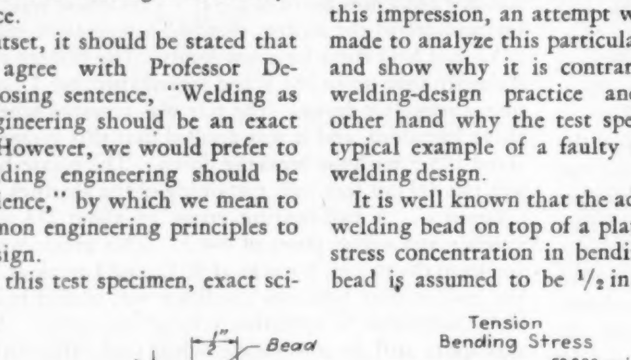


FIG. 1 (TOP); FIG. 2 (BOTTOM)

to the neutral axis of the complete section. If the bead were ground off, the section modulus due to the shorter distance to the extreme fiber would increase to 0.375 in.³, as shown in Fig. 2. If the bar in each case were supported at a 12-in. distance between supports with a load of 5000 lb applied in the middle, the bending moment would be 15,000 psi. If, now, from these data the actual stress is calculated, we find that the stress in the extreme fiber on top of the bead would be 50,000 psi, whereas the stress on top of the plate would be only 35,000 psi, as in Fig. 1. From this it is now evident that in bending it is poor practice to permit the existence of the welding bead as it is clearly a "stress raiser." It follows that if the member is to be $^1/_8$ in. high (see Fig. 1) the calculated section modulus is only 0.3 in.³ due to the increased distance from the extreme fiber

stressed in bending, as cited by Professor DeGarmo, the welding bead should be removed to eliminate the stress concentration created by the bead. Again, contrary to good practice, the stress concentration is further increased by the notch effect purposely introduced into the test specimen. It should be made clear that every welding engineer and welder is naturally trying to eliminate such stress raisers. To point this out and to follow through with stress-raiser-free designs could be called application of exact science to welding, since the afore-mentioned considerations could not be followed without knowledge of general engineering principles.

The foregoing can be further explained by saying that the specimen was purposely designed to fail in the weld, it being forced to do so by the notch effect, and that after failure in the weld the stress concentration was removed and the remaining stress over the whole remaining section of the plate was uniform and, important to point out, of a much lower magnitude than the original concentrated stress causing failure in the top of the bead. This explains why the plate was able to take additional bending after failure of the weld.

We would recommend that a test be made under similar conditions but without the notch effect. Such a condition would be a closer approach to actual desired welding conditions under which an initial failure in the weld would become doubtful. A further test made with the weld bead ground off would fall in line with best welding design, in which case we expect no initial failure in the weld, indicating that by applying known engineering principles a failure in the weld could be prevented.

It is our contention that if this notched specimen were tested in ordinary tension it would also fail in the weld, being forced to do so by the notch effect. Without the notch, of course, the stress distribution is uniform and the specimen would not necessarily fail in the weld.

In referring to loading in bending, the reference to the notched specimen is also confusing in that no mention has been made of the fact that any structure loaded in bending is calculated not only for the maximum stress due to bending but also for a permissible amount of deflection. It is understood that a structural member may deflect without failing but that an excess amount of deflection may cause

[1] "Welding and Riveting Compared," by J. F. Lincoln, Mechanical Engineering, vol. 66, 1944, p. 614.

the structure to be worthless as soon as the member is out of alignment.

From this it follows that under actual working conditions the plate would not be bent to the angle shown in the photograph, but that deflection would be limited to a few thousandths of an inch. Under actual service conditions, therefore, a member is never loaded anywhere near to destruction. Under such lower actual conditions it is probable that the specimen would not have failed even with the bead in place or even with the bead notched, both of which conditions we have already pronounced as faulty welding engineering. If a specimen were made up with or without the weld bead ground flush, and a notch had been put into the bar itself away from the weld and such a test were carried to destruction, failure undoubtedly would occur in the plate and not in the weld, forced to do so by the notch effect.

This controversy brings to mind the fact that in years gone by the only information obtainable and guiding toward good welding design was furnished by manufacturers of welding equipment; they have gone out of their way to educate those engineering circles engaged in welding, admittedly in self-interest for the promotion of their equipment, however beneficial to all designers of weldments. It gives the writer great satisfaction to repay this cost of education, which cannot be counted in dollars and cents, by supporting their belief that the science of welding engineering is still a stepchild, considering the curriculum available to the engineering students at our universities. To my knowledge there are only two or three universities now actively engaged in teaching welding design fundamentals to mechanical engineers.

In conclusion, it is granted that further progress is dependent upon support by the universities by means of extended research, but primarily by including welding design in their obligatory curriculum, and what is most important, that such teaching closely conform to our concepts of exact science. The writer believes that this is what Mr. Lincoln had in mind when he wrote his letter and it is hoped that this discussion will again bring to the foreground the urgent need of more exact science in welding engineering.

Leo Berner.[2]

To the Editor:

Mr. Berner's comments regarding the specimen with the weld bead left on are similar to those of Mr. Frederick Franz, which appeared in the August issue of Mechanical Engineering. As I pointed out in my letter in that issue, even if the raised portion of the weld is removed, such a bend test will result in failure in the weld prior to failure of the plate. We have dozens of specimens which demonstrate this fact.

I feel that Mr. Berner is unduly alarmed when he says, "In citing this specimen a wrong impression that welds are not to be trusted is created for young engineers. . . ." On the contrary I believe it does great harm for young engineers and all others not to know the whole truth regarding welding or any other subject. If there are certain conditions which must be avoided in welded construction they should be known and correct solutions found.

It is rather difficult to accept Mr. Berner's statements, (*a*) "Under actual service conditions, therefore, a member is never loaded anywhere near to destruction," and (*b*) ". . . . the general understanding that notch effect is of only minor importance for static loading conditions." If these are true, it is difficult to understand how certain ships, bridges, etc., ever became broken, and in many instances with so little deflection and elongation that it is difficult to measure.

I am in thorough agreement with Mr. Berner that more attention must be given to welded design by those in the colleges and those outside. Much of the trouble that has been experienced with welded structures in recent months may be said to be due to improper design. However, in many cases no one knew just exactly what limitations welding placed on design. Welding made it possible to fabricate certain designs which were impossible with other methods of construction. The only way to get the necessary information is to recognize problems when they arise, admit that they exist, and then by experimentation and research seek the facts and solutions. The Award Program of the James F. Lincoln Arc Welding Foundation for textbooks covering welded design may be a considerable step along the way. It is to be hoped that the resulting books will weed out some of the previously held "theories" regarding welded structures, substitute proved facts, and point out that welding does have some limitations just as other methods of fabrication. Welding has no need to fear the facts.

Progress in welding design will not be made by rising in holy wrath whenever someone points out a difficulty. These difficulties should be recognized and solutions found. The welding industry, more than anyone else, should be anxious to uncover all of these difficulties and work toward their solution.

E. Paul DeGarmo.[3]

[2] Welding Engineer, Joshua Hendy Iron Works, vice-chairman, American Welding Society, San Francisco Section.

[3] Associate Professor of Mechanical Engineering, University of California. Mem. A.S.M.E.

Dressing Grinding Wheels

Comment by B. P. Graves[4]

In this paper[5] the author is to be congratulated for bringing to the attention of the trade an old method. The writer recalls having seen this on several occasions in Germany during some of his trips as far back as 1934 to 1938.

Some of the major points regarding this process are brought out very well in this paper. From experiments by the writer's company, we were convinced that there are several limitations to this method. It is for this reason that the writer would like to ask the author if he has found it possible and practical to use the crushed-wheel method for grinding slots where the sides are parallel within a maximum tolerance of 0.001 in., these slots having dimensions of approximately $^1/_8$ in. width, running from $^1/_4$ to $^7/_{16}$ in. depth?

Further, has any advantage been found in making crushes without gashes, over crushes with gashes?

Also, which is the better method in applying the crusher to the wheel; is there any advantage in stopping the grinding wheel, allowing the crusher to act as a driver, over running the wheel at a slow speed and allowing the wheel to act as a driving member for the crusher? To date, we have found very little gain in having the wheel act as a driver, over stopping the wheel and having the crusher act as a driver. The latter can be applied more readily to the conventional type of grinding machine.

Author's Closure

The author wishes to thank Mr. Graves for his comments on the dressing of grinding wheels and will answer his questions in accordance with our experience. We have found it impractical to grind slots where the sides are parallel within 5 deg. It is possible to grind parallel sides by the crush-dressing method, but the breakdown of the wheel is rapid, and retaining parallel sides on the crushing rolls as well as the proper dimension between these parallel sides is not economically feasible. However, compromise may be made with the "rule of thumb," a 5-deg rule which we have set up, always remembering that the more nearly parallel the sides, the more uneconomical the grinding job.

The second question has to do with making crushers with and without gashes.

[4] Director of Design, Brown & Sharpe Manufacturing Company, Providence, R. I.

[5] "Dressing Grinding Wheels," by W. F. Aller, Mechanical Engineering, vol. 66, 1944, pp. 779–782.

Our experience indicates that either will work satisfactorily under the proper conditions. We find a somewhat better grinding finish when the crusher has been gashed. We believe the main advantage in gashes is due to more efficient removal of abrasives from the crusher roll during the crushing operation.

The third question asked for a statement of advantages or disadvantages of driving the crusher with the wheel or the wheel with the crusher. We have used both methods satisfactorily. It is true that with the most conventional machine tools it is easier to apply the method by driving the crusher. Greater crusher life may be expected in any case if the unit with the least resistance is driven by the other unit. Excessive drag of the driven unit adds to the slippage between the wheel and the crusher and necessarily shortens the crusher life due to abrasive action.

W. FAY ALLER.[6]

Duodecimal System

TO THE EDITOR:

The editorial[7] on metric-system discussion seems hardly complete without a reference to The Duodecimal Society of America. This organization was started about five years ago with the object of introducing duodecimal notation to supersede the decimal notation which is now universal. It has even published a book on the subject—an effort, we may think, comparable in scope to those which have been made within a century to introduce a universal language.

The fact that duodecimal notation offers very great advantages over decimal notation has never been called to the attention of engineers. As a matter of fact, the advantages are great enough to warrant the pains taken to become familiar with it by anyone who has much calculating to do. The duodecimal, or as the society more succinctly terms it, the "dozenal" system, involves, of course, not merely two new digits but a new multiplication table, and an array of terms to replace such words as hundred, thousand, and million.

At the present time agitation to substitute "dozenal" for our common decimal notation system does not seem to be practical. Yet in the course of years it does not seem at all impossible; and looking back over a long life I am filled with amazement at the sweeping changes of the sort that have been brought about in that time. And one lifetime is but a trifle in the life of the race.

I suppose no one, least of all a member of our Society, will now dispute the fact (vaguely hinted in my 1897 paper) that the Anglo Saxon race is destined to dominate the whole planet, and that without any war of conquest; it is their (and more particularly our) way of doing things and not that of the miscellaneous nations of Europe, Africa, and Asia, that is to be considered. The metric controversy was in substance settled, and settled for good, at the opening of this century. The English (as related in my paper) had already settled it as regards coinage some fifty years previously and have never seriously considered it since. If we, that means English and Americans, should take to the "dozenal" system of notation, and I think that likely to happen say two centuries hence, the metric system will then become as dead as the dodo, and we may as well take that eventuality into present consideration.

GEORGE WETMORE COLLES.[8]

[6] Director of Research, The Sheffield Corporation, Dayton, Ohio. Mem. A.S.M.E.

[7] MECHANICAL ENGINEERING, vol. 67, 1945, p. 500.

[8] Rosharon, Texas. Mem. A.S.M.E.

An Experiment in Management Education

COMMENT BY M. J. EVANS[9]

Among comments on this paper,[10] reference has been made to the necessity of introducing the element of humanity and warmth into any training program if permanent results are to be achieved. Several years ago, co-operating with a group of engineers, I instituted a research program into the broad problem of human engineering in industry in one of our Midwestern engineering schools. One of the major points we developed is that training in industrial relations must be a composite of knowledge and wisdom. To quote Dean Kimball of Cornell: "The world today possesses greater knowledge than at any previous period, but our wisdom has failed to keep pace."

Wisdom we define as the ability to use our knowledge to the best advantage for everyone concerned. Furthermore, it is a quality which cannot be separated from the individual personality. It produces a warmth and understanding that has great magnetic power. In short—it is the essence of leadership. A leader is a man who has the natural ability to attract others to him by the sheer quality of his life. He is honestly interested in people. Employees respond automatically to such a personality and are willing and anxious to be led.

If we are to educate our industrial executives with any degree of success, we must help them to achieve this quality of leadership which is so frequently overlooked. Any educational program that overlooks this factor can only achieve partial success. We also discovered that these human qualities can only be transmitted by someone in whom they have been developed. Our major problem is to teach leadership and this cannot be taught out of a book. It must be "caught." It is a contagion. Obviously, the words can be put in a book, but they will not move others to acceptance unless they are transmitted by an individual who is honestly making an effort to follow these precepts himself.

Thus we find that on these higher levels, we cannot separate the educational program from the character and personality of the teacher. A man who is not sincere, understanding, and honest, as well as capable cannot instruct other executives in these principles. He must also have a sincere and heartfelt interest in the problems of the people he is teaching.

Leadership consists in the acquisition of these intangible qualities of personality and character. Teaching on this level must come from the heart as well as the head. These principles may seem too simple to be important, but intensive study in this field of education of executives in the art of leadership has demonstrated beyond a question of a doubt that they are the only foundation on which an effective educational program can be built.

COMMENT BY W. R. MULLEE[11]

Most industrial companies had small beginnings with limited capital and facilities. Usually they were built around a product or a service, or maybe just an idea. The founders were inventors, salesmen, professional men, bankers, tradesmen, even sometimes farmers. They were the first managers who guided the growing business, purchased the original equipment, hired the first employees. The success or failure of the new company depended upon the skill of the owners in steering past the dangerous rocks of competition and making sure that sales dollars exceeded cost dollars.

Thousands of enterprises failed for thousands of reasons but mostly due to lack of management ability. Other thousands grew larger and larger mostly due to the native management ability of the owners.

As companies expanded, the management function was subdivided into many parts. Today's managers are men who came up the line as foremen, engineers, accountants, lawyers, salesmen. Many lack the original owners' native management talent but the success of the company still depends on the policies they

[9] Melvin J. Evans Company, Chicago, Ill. Mem. A.S.M.E.

[10] "An Experiment in Management Education," by R. C. Muir, MECHANICAL ENGINEERING, vol. 67, 1945, pp. 19–20 and 24.

[11] Industrial Engineer, American Hard Rubber Company, New York, N. Y. Mem. A.S.M.E.

established and the daily management decisions they make.

Another problem is that of age. The man at the top is frequently over 50, usually over 40, and his immediate subordinates frequently over 40, usually over 30. These age groups do not welcome the thought of going back to school in the accepted sense of the word. They firmly believe in education and training; but always for the man further down the ladder.

These are only two of the many reasons why management people in industry present an educational problem far different from that in colleges and universities. We cannot use our academic yardsticks to measure their effectiveness. We must make comparisons with successful industrial-training plans. Fortunately, we have the tremendous experience of wartime-training plans. Over one and a half million industrial executives from presidents to gang bosses have taken the "Training Within Industry" courses, "Job Instructor Training," "Job Methods Training," and "Job Relations Training." This is the largest industrial training job ever undertaken. Herewith are ten items that helped make these courses successful. Compare them with the plan of the author's company, and the reader may then draw his own conclusions:

1 The courses were laid out for five 2-hour sessions.

2 Project material was chosen by the class directly from daily factory operations.

3 Sessions were informal, avoiding schoolroom atmosphere.

4 Groups were limited to 10 or 12 per class.

5 Students took turns conducting the sessions.

6 Projects were demonstrated, not merely discussed.

7 Demonstrations were assigned and prepared in advance of the meeting.

8 The instructor conducted the first session and thereafter remained in the background.

9 Groups were composed of men in related jobs, promoting teamwork.

10 The student could see the personal benefit in successfully completing the course.

COMMENT BY A. L. WILLISTON[12]

There seems to be quite general agreement on the fact that both in native personality and in technical background of training and equipment the "industrial manager" is very definitely a different type of individual from, say, the designing engineer, the production engineer, or the technical salesman.

Furthermore, there seems to be agreement on the importance of having a sufficient number of thoroughly competent and efficient managers if American industry is to prosper most effectively in future years.

The discussion therefore centers upon the question of how to secure them in needed quantity and quality.

The answer is simple if we engineers could only learn to approach these human problems in the same "scientific spirit" that we are always accustomed to use in dealing with our problems in other fields of engineering.

In designing a part for a machine tool or an automobile, for example, there are three steps to take:

1 We determine the conditions that the part must meet in service; the load that it must carry, etc.

2 We select a material, such as bronze, steel, aluminum, or what not, that by scientific test is found to be suitable for our purpose.

3 By a known and tested process, we transform the appropriate material into the desired form and condition that is required to meet the specifications.

I have always felt that it was a sad commentary on our engineering profession that we never have effectively used these three obvious and necessary steps in dealing with human material. And the consequent loss in efficiency in handling the manpower in American industry is truly appalling.

We know that human beings vary in their fundamental characteristics quite as much as do metals or other materials of construction. We also know that human nature is "malleable," and can be reshaped or changed in the direction we desire through exposure to selected opportunities of habit formation and properly chosen environment.

If the reader doubts this latter statement, let me ask if he ever knew a West Point graduate who was a physical coward? Yet, the raw material that enters the freshman class of the Military Academy is an average sample. Or, again, the physician who has had a wide general practice is sure to have a different quality and understanding of human sympathy from the boy who entered the medical school.

Illustrations might be multiplied, but these two examples are sufficient to demonstrate that, to a far greater extent than most persons imagine, we may, if we would only take the trouble to learn how, mold human nature to our will.

And, may I close with a quotation that I especially like, from Charles Proteus Steinmetz, who as you know was a very wise person as well as a most eminent scientist and engineer. And I am sure that Dr. Steinmetz would have included these human values that we are discussing within his definition of "spiritual forces." He is known to have remarked: "When the world gives the same attention to discovery in spiritual realms that, during the past half century, it has given to discovery in material fields, civilization will make more progress in decades than it previously has made in centuries."

Why, as engineers, cannot we take this vital principle of Dr. Steinmetz to heart and seriously start to deal with these problems of human selection, development, and orientation with the same masterly skill that has made our material achievements so brilliant?

Air-Cargo Handling

COMMENT BY C. G. PETERSON[13]

Air-cargo handling[14] is not an academic problem for the postwar days because the daily volume of air express being handled over the air lines of the United States by Railway Express Agency is in such appreciable volume that any means for expediting the handling and decreasing the cost thereof will be of immediate benefit.

The volume of air express for 1944 is as follows:

	Year 1944	Daily average, baseds on 365 day
Shipments.........	1,773,823	4,830
Gross revenue.....	$11,451,165	$31,200
Weight of shipments, tons.....	17,138	47
Average length of haul, miles......	992	

Speed of Vehicle Service. Speed is the essence of air express. It is as essential in ground operations as in flying operations. Time studies recently made at twelve of the largest air-express traffic points indicate that 73.6 per cent of the air shipments were delivered to consignees in an average elapsed time of 71 min after the arrival of the plane at the airport. (Necessary allowances made for consignees not open during the night.) As many of the fleet of 15,000 Railway Express street vehicles as are necessary are used to provide this fast vehicle service. In April, 1942, a total of 4652 different R.E.A. vehicles were used in handling air express. In that month, 57,570 shipments out of a total of 120,954 were handled in combination vehicle service, i.e., vehicles which carry both rail express and air express on the same trip.

Off-Air-Line Shipments. It is estimated that 30 per cent of the air-express shipments moved part way by rail, either to or from the 22,000 offices of Railway Express which are located at points not

[12] Dedham, Mass. Mem. A.S.M.E.

[13] Chief Engineer, Railway Express Agency, Inc.

[14] "Air Transport Command Air-Cargo Problems," by H. R. Harris, MECHANICAL ENGINEERING, vol. 67, 1945, pp. 572–574.

directly on these air lines, or shipments that move part way by rail in substituted service to expedite delivery.

Estimates for August, 1944, indicate there were 37,293 shipments to or from off-air-line cities and 110,206 shipments between airport cities. The gross revenue on these off-air-line shipments was bigger and better ($9.48 per shipment) than the shipments between airport cities ($6.23 per shipment), resulting in a gross air-express revenue of $353,925 on the off-air-line shipments against $688,306 for shipments between airport cities.

Ton-Miles. The C.A.A. figure for the ton-miles of air express for the calendar year 1944 is 17,623,838. For that year, the air-mail ton-miles are reported by the C.A.A. as 50,775,373. The gross revenue per ton-mile of air express, which in 1938 was 88.35 cents, dropped to approximately 65 cents per ton-mile for the third quarter of 1944. It is estimated that the less-carload rail express of R.E.A. for the year 1942 was 2,462,000,000 ton-miles, with an average weight per shipment of 55 lb and an average haul of 550 miles with a gross revenue of 9.14 cents per ton-mile. It is estimated that the total number of shipments handled by R.E.A. in 1944 was 197,443,000.

Number of Handlings. It is estimated that each air-express shipment has a minimum of 12 individual physical handlings. Thus for an average of 4870 air shipments per day, there is something like a minimum of 60,000 physical handlings.

Magnesium Roller Conveyers. The Express Agency has been a leader in developing lightweight roller conveyers, specifications calling for magnesium to give extreme lightweight to facilitate the movement of the conveyers by the men operating them. There are some 27,000 linear ft of roller conveyers in use in R.E.A. terminals, and many of the air-express offices are equipped with them.

Growth of Air Express. Percentagewise, the increase in air express has been larger than the increase in passenger or air-mail traffic, as shown by the following:

INCREASES IN AIR-LINE TRAFFIC DERIVED FROM C.A.B. REPORTS; FISCAL YEARS 1938 TO 1944

	Per cent
Air-express revenue	540
Passenger revenue	308
Air-mail revenue	90
Air-express pound-miles	668
Revenue passenger-miles	313
Air-mail pound-miles	500

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Occupational Accident Prevention

OCCUPATIONAL ACCIDENT PREVENTION. By Harry H. Judson and James M. Brown. John Wiley & Sons, Inc., New York, N. Y., 1944. Cloth, $5^1/_2 \times 8^3/_4$ in., 234 pp., $2.75.

REVIEWED BY HARRY W. GABOR[1]

THIS little volume of 220 pages with appendix contains a comprehensive presentation of up-to-date tested methods of successful industrial accident control, now operating in many plants, small, medium, and large. In concise fashion it covers basic principles of a large subject in small space.

This book details various hazards to which average industrial employees are exposed, how those hazards may be recognized, the injuries which may result therefrom, together with the reasons for such injuries, and, most important, the demonstrably successful methods of preventing the majority of the accidents that produce those injuries.

The authors have introduced a new and different approach to the problem of industrial accident prevention. A number of books on this subject have been written from outside of the shop by the authors looking in, but this book has been written within the shop by those who have direct and intimate contact and responsibility for the problems including physical hazards, job aptitude and placement tests, safety training, and supervision of the workers.

[1] Chairman, A.S.M.E. Safety Division, Metropolitan Section.

They emphasize that responsibility for applying safety measures rests upon management and foremen who should have both the duty of applying such measures and credit for good results. They point out that original and continuous management interest is the most effective stimulant for the plant program and why supervisors must co-ordinate their efforts with the management to gain and hold co-operation of plant personnel.

They make clear, in simple language, the steps to be followed by executives in establishing an effective program in their own plants, small or medium-sized, the type of program best suited to certain industries, and who should be brought into the program with their functions. The position and duties of a safety director are detailed together with the type of plant which has problems of sufficient magnitude to warrant employment of a special staff assistant in that advisory position.

The foremen's conference method of training supervisors is explained in simple terms with brief references to plants in which this system is presently being conducted on a successful basis. Emphasis is placed upon the need of fitting the training program to the special requirements of the particular plant in which that program is to be installed. Attention is directed to the value of positive appeal in advertising accident-prevention methods, that individual employee interest may be developed by simple posters and figures with encouragement to them to participate by suggestions for improved methods for better and safer production. Giving recognition to valuable suggestions is pointed out as a means of maintaining interest and support of employees in the plant safety program.

Under accident causes this book makes clear that most accidents have their origin in improper and inefficient work habits, not corrected by impatience of supervisors but rather needing corrective action by first ascertaining the exact cause in order to determine accurately what is needed to prevent a recurrence. Effective planning of a job step by step is explained in penetrating detail with due regard to all production and accident-creating factors, how accidents can be prevented, and the position of the foreman in this picture.

This book leaves no doubt in the reader's mind regarding the authors' familiarity with the subject matter, the practicability of their suggestions relating to material handling, and the clarity of their observations on most efficient work methods. They are on firm ground with their statement, "handling of materials is one of the major sources of injuries." The authors recognize and point out the importance of eliminating physical hazards by proper design or safeguarding, the need for adequate, nonglare illumination, how material-handling, production, and plant housekeeping methods may be improved, and how

employee interest may be encouraged in better plant maintenance.

This book is a compendium of that information which the plant manager or safety director needs in order that he may keep the plant operating productively with a satisfactorily low accident-frequency rate. Since accidents waste money their prevention is necessary economy in every plant. The use of this book as reference and guide will save him much time and worry.

Business Leadership in the Large Corporation

Business Leadership in the Large Corporation. By R. A. Gordon. The Brookings Institution, Washington, D. C., 1945. Cloth, 5¼ × 8 in., 369 pp., $3.

Reviewed by Paul E. Holden[2]

THERE is a well-recognized paucity of literature in the field of top management in large enterprises. Hence any new and worth-while volume, such as the one under review, is a welcome addition.

By the author's definition, "business leadership in the large firm includes initiation and approval of decisions affecting important economic variables which have a strong impact on the firm's activities (including choice of the men who make these decisions) and coordination or the creation and maintenance of organization." The author designates the large firm or corporation as one with assets of fifty million dollars or more.

The essence of the book is contained in the following quotation:

"Upon corporation officials, from the chief executive to subordinate officers such as the sales or production manager, has devolved primary responsibility for the exercise of business leadership in the modern large corporation. Although there are exceptions, the general rule is that corporate executives as a group determine the volume and direction of investment in their firms; they set prices and formulate price policies; and, in general, they make the other important decisions which constitute the heart of what many economists call the entrepreneurial function—the function which we have called business leadership. To say this is not to deny the existence of the varying degrees of influence exerted by interest groups, nor is it to imply that boards of directors uniformly serve in merely an ornamental capacity. But in general—for the range of large corporations covered in this study—the leadership role of the executive cannot be questioned."

This general thesis is developed logically and systematically through fourteen chapters. These, in part, discuss such pertinent matters as: The prevalence of the corporate form of business organization; the relative importance of the large-scale enterprise; management's financial stake in the large corporation; compensation of executives; the significance of nonfinancial incentives. Not a little space is devoted to various aspects of the corporate board of directors including comments on its size and composition, the passive character of most boards, and the functioning of the influential director.

Of particular interest to this reviewer are the chapters dealing with the professionalization of business leadership, and with the influence of interest or pressure groups, viz., minority stockholders, financial institutions, government, competitors, customers, and labor.

The informed reader will not find in this book any startlingly new ideas but he will find a well-documented, effective, and cogently presented thesis with respect to present-day corporate management. For the most part, no serious issue can be taken with the various conclusions which the author derives. However, one conspicuous exception to this general statement should be mentioned. Few businessmen will accept the author's opinion regarding the means by which the board of directors shall perform its primary functions "freed of the possibility of management domination." His view on this matter is expressed, not without some misgivings to be sure, as follows: "Given management's control of the proxy machinery, the weakness of stockholders, and the fact that management's obligations are too broad for control to come from any single group, we are led to the conclusion that government intervention of some sort is necessary."

Unlike most theoretical economists, the author writes with an understanding and sympathetic viewpoint regarding corporate management practice. He gives every evidence of being objective in his presentation and he does not seem to feel called upon to deprecate either large business enterprises or the relatively small group of men who give leadership to corporate operations.

The book is not intended to furnish specific answers to problems which confront key executives in large corporations. Neither will it provide the basis by which a company can review its own management practices in any detail. Nevertheless, it is this reviewer's opinion that the volume is worth-while reading both for the business executive and the student of business.

[2] Professor of Industrial Management, Graduate School of Business, Stanford University, Stanford University, Calif. Mem. A.S.M.E.

Thermodynamic Properties of Air

Thermodynamic Properties of Air. By Joseph H. Keenan and Joseph Kaye. John Wiley and Sons, Inc., New York, N. Y., 1945. Cloth, 7⅞ × 10 in., 73 pp., 3 figs., $2.25.

Reviewed by John A. Goff[3]

CONSIDERED not so much a contribution to our knowledge of the thermodynamic properties of air as a device for expediting some of the calculations encountered in gas-turbine and air-compressor design, in which the demands for accuracy are not too exacting, "Thermodynamic Properties of Air" will be welcomed by many engineers. Table 1, Air at Low Pressures, has already been reduced to convenient chart form by the Research and Standards Branch of the Bureau of Ships, Navy Department, in Research Memorandum No. 6-44 entitled, "Gas-Turbine Gas Charts."

Statistical mechanics predicts that the pressure-volume product pv, the enthalpy h, and the reduced entropy $s + R \log_e p$ of a gas approach finite values as pressure is reduced toward zero along an isotherm. Except at inaccessibly low temperatures, the zero-pressure value of the product pv is strictly proportional to absolute temperature T. If specific volume v is expressed in terms of the mol as unit of weight, the constant of proportionality becomes a universal constant R whose value is known with a high degree of accuracy. The zero-pressure values of enthalpy and reduced entropy, the latter of which the authors have denoted by the Greek letter ϕ, are directly calculable from spectroscopic data, the uncertainties in the data themselves and in the fundamental physical constants (Avogadro's number, Boltzmann's constant, Planck's constant, speed of light) determining the accuracy of the calculated results.

Statistical mechanics further predicts that the zero-pressure values of the product pv, the enthalpy h, and the reduced entropy $s + R \log_e p$ of a gas mixture of fixed composition, such as air, are sums of separate contributions from the individual constituents. Therefore, since accurate spectroscopic data for all constituents of air and accurate values of the fundamental physical constants are now available, it should be possible to compute values of the various zero-pressure properties of air possessing as high a degree of accuracy as does the assumed composition.

[3] Dean, Towne Scientific School, University of Pennsylvania, Philadelphia, Pa. Mem. A.S.M.E.

The authors assume a composition for air without any discussion of its probable accuracy. They then base their calculations of zero-pressure properties on the state-sum calculations of Johnston and Davis for nitrogen and of Johnston and Walker for oxygen, which were themselves based on less accurate spectroscopic data and less accurate values of the fundamental physical constants than are now available. These state-sum calculations were carried out for relatively few temperatures too widely spaced for accurate interpolation except by the use of semi-theoretical control equations which are rather complicated. The interpolation method employed by Heck, whose data have been used in constructing Table 1, is definitely inadequate. For these and other reasons the data in Table 1 are not to be regarded as definitive. What revisions a more critical treatment of the problem will dictate are difficult to estimate, but it seems safe to predict that they will be appreciable, especially at the higher temperatures.

At finite pressures the values of the product pv, the enthalpy h, and the reduced entropy $s + R \log_e p$ of a gas differ appreciably from their respective zero-pressure values; and corresponding values for a gas mixture can no longer be obtained by simply adding separate contributions from its individual constituents. These complications are due to intermolecular forces and, although modern physical theory has registered some striking successes in subjecting them to quantitative analysis, the authors have seen fit to ignore them completely in order to achieve simplicity. The procedure is thermodynamically consistent and quite justifiable so long as it is clearly indicated that it involves some sacrifice of accuracy even at fairly low pressures.

The principal merit of the book is its timely appearance when interest in the development of the gas turbine is so high. The format is excellent, the tables being especially easy to read. The introduction of such fictitious concepts as relative pressure and relative volume may be regretted if they, like Dalton's partial pressures, become so firmly embedded in the thinking of those who learn to use them that they become obstructions to thermodynamic progress.

Besides Table 1, Air at Low Pressures, the book contains a Table 3, Specific Heats, Ratio of Specific Heats, Velocity of Sound, Maximum Flow per Unit Area, Viscosity, Thermal Conductivity, and Prandtl Number for Air. In addition there are tables of logarithms, of useful polytropic functions, and of frequently needed conversion factors.

The reader will be confused to note, on page 36, that 1 lb/sec ft = 0.031081 lb sec/ft² which, interpreted literally, would mean that 1 ft = 0.031081 sec². Either this is a typographical error or the authors expect the reader to understand that the symbol "lb" denotes the unit of weight on the left of the dimensional equation but the unit of mass on the right. Incidentally, the authors have departed from the usual practice in thermodynamics in defining h, for example, as enthalpy per unit mass (Btu/lb) instead of enthalpy per unit weight (Btu/lb). They seem to believe that mass is a concept more fundamental than force. While it is true that the unit of force varies with location in the earth's gravitational field, it is also true that the unit of mass varies with velocity. The writer that no consistent system of units is more fundamental than any other and fails to see the advantage of departing from usual practice as the authors have done.

The Coming Age of Rocket Power

THE COMING AGE OF ROCKET POWER. By G. Edward Pendray. Harper & Brothers, New York, N. Y., 1945. Cloth, $5^1/_4 \times 8^1/_2$ in., 244 pp., 19 figs., 23 plates. $3.50.

REVIEWED BY C. RICHARD SODERBERG[4]

THE war has brought to practical fulfillment many of the dreams of daring men, dreams which the rest of us persisted in labeling as unrealistic. The development of rocket propulsion during the war has indeed been a vindication of the faith of the early rocket enthusiasts. Mr. Pendray was one of the organizers of the American Rocket Society in 1930, and he is undoubtedly one of the best qualified to give a survey of the history of this subject. The less striking aspects, such as the regular jet propulsion of airplanes, receive their attention, but the principal theme relates to rockets and rocket-propelled missiles. The author's enthusiasm for the subject is apparent throughout the book, and as a result there is a zest to it which carries one through in spite of the unavoidable dryness and superficiality of technical descriptions addressed to the layman.

The subject matter is developed in orderly steps from an exposition of the fundamentals involved in the first two chapters to a classification of types of reaction motors and a brief résumé of present-day achievements, in the third chapter. Chapter 4 is devoted to the jet-propulsion problem. The remainder of the book deals chiefly with the main theme, the rocket. There is an abundance of interesting incidental details in this sketch of the history of the rocket, which is certain to be new to the reader who is not a confirmed rocket enthusiast. Most of us would have assumed that the reference to "rocket's red glare" in our National Anthem stemmed from forgivable poetic license, but apparently this is not so; the British actually did bombard Fort McHenry with Congreve rockets. Apparently, the military rocket played the role of a major weapon at that period.

The work of Goddard in our own time is given much attention, particularly his patient, systematic study of the rocket problem, which has often been forgotten in the flurries of newspaper publicity on moon rockets and other fantastic schemes. This book performs a useful service in confronting the reader with the enormous spread between the attainments of this serious rocket research and the requirements for any of the publicity stunts, which from time to time have caught the public's fancy.

The developments of rocket missiles of this war are covered rather more fully than one would expect in this period of secrecy in such matters. The culmination of this subject naturally falls on the German V-1 and V-2 projectiles.

The concluding three chapters present some of the realities surrounding the problem of interplanetary travel, and the possibilities of nonmilitary applications of rocket flights. In spite of the author's enthusiasm, his figures leave the reviewer with a comfortable feeling that wide use of rockets and rocket travel in our civilian world is still a long way off.

The book appears to be remarkably free from major technical errors, which are not easily avoided in dealing with a subject of highly technical character in essentially nontechnical language. The statement on page 46 that "the mechanical efficiency of the reaction motor.... is highest when the motor is moving at the velocity of the ejected gases" does not seem to be true for the air-stream engines. The efficiency by which fuel energy is converted into propulsion work in the jet-propulsion airplane, for example, theoretically increases without limit as the plane velocity is increased. The possibilities of the Melot thrust augmenter, mentioned on page 48, are related to the fact that they depend on momentum exchange, in which kinetic energy is necessarily lost and would seem to justify less hope of these devices than is implied. The author gives much attention to exactness in reproduction of foreign titles and phrases, the only error caught by the reviewer being the Swedish name for rocket which is *raket* rather than racket. It is a matter of regret to the reviewer that the monstrosity "athodyd" is encouraged in its undeserved survival.

All in all it is a very readable book, worth while to the technical expert as well as to the layman.

[4] Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. Mem. A.S.M.E.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Plans for 1945 Annual Meeting of A.S.M.E. Now Being Made

Hotel Pennsylvania, New York, Will Again Be Headquarters During Week of November 25

VARIOUS program-making agencies of The American Society of Mechanical Engineers are hard at work on plans for the the 1945 Annual Meeting of the Society.

Headquarters at Hotel Pennsylvania

The meeting will be held at Hotel Pennsylvania, New York, N. Y., the week beginning Sunday, November 25. There is some question regarding Thanksgiving Day. In New York State a law has been passed making the fourth Thursday of November, Thanksgiving Day. For federal purposes a similar law has been passed by Congress.

"Air power" will be featured appropriately by the Society because this is the twenty-fifth anniversary of the formation of the A.S.M.E. Aviation Division.

The November issue will contain a comprehensive outline of the program but it is now possible to give a general statement which is indicative of an important meeting in this important reconversion period.

Divisions Sponsoring Sessions

The Applied Mechanics Division is planning for two sessions and a dinner and for four other sessions under joint sponsorship with the Aviation, Railroad, Power, and Management Divisions.

The Aviation Division will hold a twenty-fifth anniversary dinner in addition to four technical sessions.

The Consulting Engineering Group is scheduling a round-table discussion.

The Committee on Education and Training for the Industries is arranging a forum and panel discussion.

Fuels will be discussed along the lines of railroad requirements as originally planned for the Chicago Semi-Annual Meeting, but canceled on account of O.D.T. regulations.

The Heat Transfer Division will sponsor two sessions.

The Industrial Instruments and Regulators Division will hold three sessions on Tuesday morning, afternoon, and evening.

The Management Division is planning a half dozen sessions in addition to the usual annual luncheon.

The Oil and Gas Power Division will sponsor four sessions, of which one will be devoted to oil and gas power, two to gas turbines, held jointly with other divisions. The fourth will be a gas-turbine symposium held jointly with the Power Division and The Society of Naval Architects and Marine Engineers. The Division is also planning for two luncheons.

The Power Division will hold a session devoted to a discussion of the Montauk Plant and a symposium on Marine Power.

The Railroad Division's program includes such papers as "Solid Fuels in Railroad Motive Power," "The Pennsylvania Turb-Mechanical Locomotive," and "Modern Passenger-Car Design."

The Wood Industries Division's program will extend over two days with three sessions on Tuesday morning, afternoon, and evening and a dinner on Tuesday evening. Two plant trips are scheduled for Wednesday morning and afternoon.

Make Reservations Promptly

Members requiring hotel rooms should promptly make reservations at their favorite hotel, sending a copy to the Society Headquarters. Likewise, members interested in attending the annual dinner on Wednesday evening, November 28, should notify the Secretary.

Actions of A.S.M.E. Executive Committee

At Meeting Held at Headquarters, Aug. 22, 1945

A MEETING of the Executive Committee of the Council of The American Society of Mechanical Engineers was held at Society headquarters, New York, N. Y., on Aug. 22, 1945. There were present: Alex D. Bailey, chairman, R. F. Gagg, vice-chairman, and A. R. Stevenson, Jr., of the Committee; J. J. Swan (Finance); C. E. Davies, secretary, and Ernest Hartford, executive assistant secretary.

The following actions were of general interest:

Personnel Service

The Committee noted that Ernest Hartford had been chosen president of the Engineering Societies Personnel Service, Inc.

Resignation Accepted

The resignation of L. A. Appley as representative of the Society on the Joint Committee on the Economic Status of the Engineer and also as chairman of the Executive Committee of the Management Division was accepted with regret.

Certificates of Appreciation

The president presented to William D. Ennis, treasurer of the Society from 1935 through 1944, a certificate of appreciation signed by presidents of the Society under whom he had served and members of the Finance Committee with whom he had been associated.

Upon recommendation of the Boiler Code Committee the Executive Committee voted to grant a certificate of award to F. L. Fairbanks for work on the Boiler Code Committee in formulating rules for welding.

Development Fund

It was reported that contributions to the Development Fund as of Aug. 17, 1945, amounted to $92,904.

Student Branches

On recommendation of the Committee on Relations With Colleges establishment of an A.S.M.E. student branch at the University of Rochester, Rochester, N. Y., was authorized.

Appointments

Approval was voted of the following appointments:

Finance Committee, A. J. Kerr, Council representative, to replace D. S. Ellis.

A.S.M.E. Sectional Committee on Minimum Requirements for Plumbing and Standardization of Plumbing Equipment, Albert H. Morgan.

Joint I.E.S.-A.S.M.E. Textile Division on Study of Textile Mill Lighting, J. M. Shute, H. C. R. Folmer, E. L. Scruggs, T. O. Sills, and L. W. Burdelle.

1946 A.S.M.E. Mechanical Catalog and Directory Out

800 Pages of Information

THE thirty-fifth annual A.S.M.E. Mechanical Catalog and Directory, 1946 edition, will be distributed to A.S.M.E. members during October.

In its catalog section, manufacturers describe and illustrate their products that are of interest to mechanical engineers. This section is followed by a Directory which gives the user a practically complete and authoritative index to manufacturers of metals and alloys, power-plant equipment, power-transmission equip-

ment, instruments, materials-handling apparatus, aircraft power plants and instruments, foundry and machine-shop equipment, heating, ventilating, and air-conditioning equipment, electric motors and controls, equipment for process industries, pumps, fans, compressors, and many other types of mechanical apparatus. A page-reference system in the Directory ties up with the catalog, providing descriptions of the desired machine or equipment.

According to the editors of the volume, it is the only book which covers the field of mechanical engineering so thoroughly.

A 16-page insert describing all A.S.M.E. publications, such as power-test, boiler-construction, and safety codes, American Standards, fluid meters, engineering biographies, bibliographies, research reports, and manuals, is included in this volume for the ready reference of A.S.M.E. members as well as other users.

New A.S.A. Color Code Completed

THE American Standards Association has announced publication of the new Safety Color Code for Marking Physical Hazards developed by one of its war committees. Purpose of this code is to unify on a national scale the colored markings used to warn employees of certain physical dangers to be avoided, to mark the location of safety equipment, and to identify other protective equipment.

Briefly, the standard is a codification of certain already recognized concepts regarding use of color for safety purposes. Much of the standard deals with suggested applications for these colors such as the marking of safety cans, fire sirens, posts, handrails, unguarded edges of platforms, location of gas masks, stretchers, etc.

Copies of the American War Standard Safety Color Code for Marking Physical Hazards, Z53.1-1945, may be purchased from the American Standards Association, 70 East 45th Street, New York 17, N. Y.

P. S. Millar Awarded I.E.S. Gold Medal

THE I.E.S. Gold Medal, given by the Illuminating Engineering Society as highest honor in the field of lighting, has been awarded to Preston S. Millar, president of the Electrical Testing Laboratories, Inc., New York, N. Y. The I.E.S. Gold Medal is awarded to eligible candidates from the fields of engineering, design, applied illumination, optics, ophthalmology, lighting research, education, or administration "in recognition of meritorious achievement which has conspicuously furthered the profession, art, or knowledge of illuminating engineering."

"Catalog Briefs"

IN this issue, page 31 to page 60 of the advertising section, are listed 292 items concerning the latest available catalogs, bulletins, and literature covering engineering equipment, materials, supplies, and services. Use the coupon on page 33 to make a selection.

Courses in Gas Turbines Outlined by A.S.M.E. Committee

FOR the purpose of outlining a course of study in the rapidly developing field of gas turbines the Co-Ordinating Committee on Gas Turbines of the Oil and Gas Power Division of The American Society of Mechanical Engineers, appointed a subcommittee consisting of Prof. C. W. Good, assistant director, department of engineering research, College of Engineering, University of Michigan, and Prof. C. R. Soderberg, of the Massachusetts Institute of Technology.

The outline was prepared by this subcommittee with the understanding that it would be given to students who have had only an elementary course in heat engines and thermodynamics. The method of presentation involves a study of ideal cycles based on perfect gases, followed by modifications which will be necessary for actual cycles.

Outline of Course

The proposed outline is as follows:

I INTRODUCTION.

General discussion of the subject and a statement of the subject matter to be covered in the course.

II THERMODYNAMICS OF PERFECT GASES.

Perfect gases would be defined. *PVT* relationships with the resulting formulations including gas mixtures would then be given. This would be followed by the kinetic theory and its relation to work in heat transfer. Energy conditions of the gases would then be considered, principally internal energy and enthalpy. The constant-volume, constant-pressure, constant-temperature, and adiabatic heat processes would be given, followed by a study of specific heats and relationship to heat processes. Enthalpy relationships and studies of the availability and reversibility would then follow.

III IDEAL CYCLES.

Based on perfect gases and constant-pressure combustion.

First the single cycle with unit adiabatic compression and expansion and heat added and rejected at constant pressure. The pressure, specific-volume diagram, and the temperature entropy diagram would be studied with the determination of equations for efficiency based on pressure and temperature, respectively. The effect of heat recovery from exhaust would then be determined, assuming that the recovered heat is supplied to the air from the compressor. The cycle with partial expansion followed by further heating, and then the cycle using partial compression followed by cooling would be considered and, later, combinations of these with and without heat exchangers.

IV WORKING MEDIA.

This would be a study of actual gases showing how these vary from perfect gases in so far as the size and attraction of the molecules is concerned, the modifications of the gas equation to take care of these variations; and critical temperature and pressure would be studied. Variable specific heats, both temperature and with pressure, would be studied and factors such as homogeneity, diffusion, and turbulence would be considered. Working media using an air base would then be considered together with the effect of different cycles on the air. Effects of reaction rates, equilibria, completeness of combustion, and quenching, would be included.

V FUELS.

These would be limited to substances which would react with the oxygen in the air to produce heat and gaseous products. Sources of fuels, fuel elements, fuels without hydrogen, fuels with hydrogen, would be considered, including hydrocarbons and alcohols. Information regarding the different hydrocarbon series would be given. Solid fuels would be discussed briefly while information on the testing and specification of liquid fuels would be included.

VI COMBUSTION.

The general picture of what goes on when the reaction occurs would be given, showing the chain character of the reaction. A study of the starting of reactions, ignition, and the part played by heat would be considered. This would be followed by flame-propagation studies, particularly showing the effect of the pressure conditions on the speed, also the effect of mixture conditions. The combustion equations for carbon, carbon monoxide, hydrogen, hydrocarbons, and alcohols with oxygen and with air would be given, to be followed by a study of heats of formation and heats of combustion. Consideration would then be given to the products of combustion, including the exhaust-gas analysis and the effects of incomplete combustion, equilibrium conditions, quenching effects, etc.

VII ACTUAL CYCLES.

In actual cycles, variations of the actual gases from perfect gases and their influence on cycle efficiency would be considered. The effect of value of the ratio of the heats would be shown. Also the effect of efficiencies of the compressor, turbine, and heat exchangers would be given as well as the limitations imposed by temperatures which materials can stand.

VIII TURBINES.

The study would be restricted to turbines utilizing steady flow. It would show how the power is obtained from the forces of the moving gases resulting from changes of momentum. Two types, impulse and reaction, would be considered, followed by analysis with ideal flow through the turbine. Nozzles would be considered and the effect of convergence and divergence as well as nozzle angle and height would be considered. The theory underlying the buckets or moving blades would be considered. The advantages of single- and multiple-stage turbines would be reviewed. The effect of friction losses and their influence on the number of stages would be considered. Limitations as to wheel speed would also be considered.

IX COMPRESSORS.

The function of the compressor would be studied and the various types such as the dis-

placement, both adiabatic and Roots type centrifugal and the propeller or axial-flow type would be studied. The actual efficiencies with various types of adiabatic displacement compressors as well as the Roots type displacement compressor would be studied, followed by the centrifugal and axial-flow types.

X Combustion Chambers.

Studies would deal mainly with the chambers for liquid and gaseous fuels, although consideration of the problems in handling solid fuels would also be given.

XI Auxiliaries.

Auxiliaries including heat exchangers, starters, ignition systems, etc., would be given.

XII Material.

This would include the materials for the rotors, blades, cases, nozzles, combustion chambers, heat exchangers, etc., and would show the influence of stress temperature, corrosion, and erosion on the choice. Also the limitations which temperature and stress would impose.

XIII Performance.

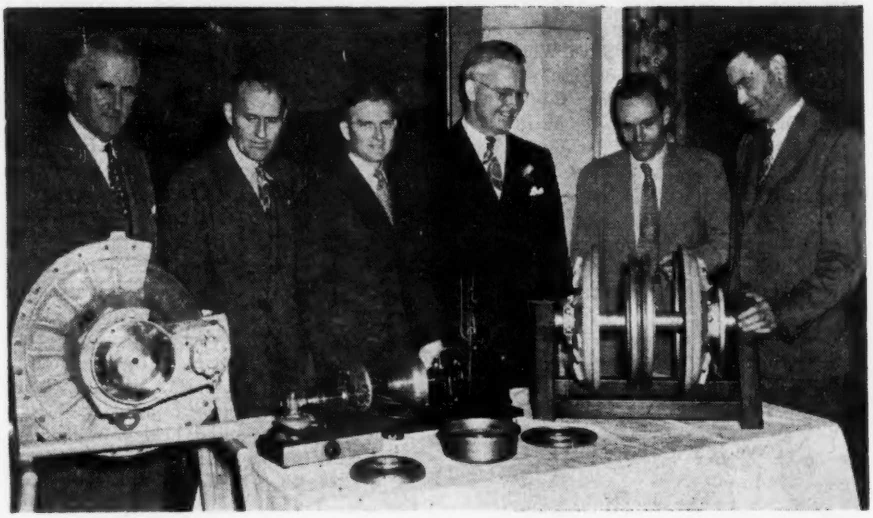
Limiting factors on performance, size, and outputs would be considered and comparison made of actual with theoretical efficiencies and with other types of heat engines, including heat-balance diagrams.

XIV Applications.

Including central station, industrial, marine, railway, automotive, and aviation.

Water Conference

THE Sixth Annual Water Conference of the Engineers' Society of Western Pennsylvania will be held in the Hotel William Penn, Pittsburgh, Pa., on Monday and Tuesday, Oct. 22 and 23, 1945. The Conference, under the chairmanship of H. M. Olson, will be held in conjunction with the Civil Section of the Engineers' Society of Western Pennsylvania. The program contains papers on boiler and industrial water treatment and related subjects.



INTERESTED SPECTATORS AT THE MEETING ON JULY 12 OF THE HYDRAULIC DIVISION OF THE SOUTHERN CALIFORNIA SECTION

Local Sections

Southern California Section Starts Its New Season

THE new fiscal year got off to a very promising start for the Southern California Section. Two meetings were held during July and one in August.

The Hydraulic Division of the Section held a dinner meeting on July 12 at the Elks Club, Los Angeles, Calif., when the subject was "Hydraulic Drives." T. J. White, district engineer, American Blower Corporation, San Francisco, gave a paper entitled "Basic Principles and Applications of Hydraulic Couplings." He was followed by N. A. D'Arcy, Charles W. Carter Company, Los Angeles, representatives of the Twin Disc Clutch Company. Mr. D'Arcy's subject was "Hydraulic Torque Converters—their Characteristics and Applications." A discussion period followed the presentation of the papers. Among the 250 members and guests present were members of the California Natural Gasoline Association and the American Institute of Mining and Metallurgical Engineers, to whom special invitations were sent.

On July 19 an evening meeting was held in Edison Hall, Los Angeles, Calif., when C. D. Allen, member A.S.M.E., Baldwin Locomotive Works, and Donald R. Jenkins, junior member A.S.M.E., Westinghouse Electric Corporation, jointly presented papers pertaining to "The S-2 Geared-Turbine Locomotive." Detailed information was given covering this

SPEAKERS' TABLE AT DINNER MEETING, JULY 12, OF SOUTHERN CALIFORNIA SECTION

(*Right to left:* V. A. Peterson, secretary-treasurer, Southern California Section; P. F. O'Brien, vice-president A.S.M.E. Student Branch, University of Southern California; John Nash, president A.S.M.E. Student Branch, University of Southern California; C. M. Sandland, C. F. Braun and Company; Marion Arnold, chairman C.N.G.A.; J. Calvin Brown, vice-president-elect, A.S.M.E.; Prof. Robert L. Daugherty, past vice-president, A.S.M.E., California Institute of Technology; Joe S. Earhart, vice-chairman, Southern California Section; Mrs. T. J. White; T. J. White, American Blower Corporation, San Francisco, Calif.; Mrs. N. D'Arcy; N. D'Arcy, Chas. W. Carter Co., Los Angeles, Calif.)

new type of locomotive which has been built as a joint venture by the Pennsylvania Railroad, Baldwin Locomotive Works, and Westinghouse Electric Corporation.

"The Southern California Co-Operative Wind Tunnel" was the subject heard at the Aug. 21 meeting held at the Pasadena Athletic Club, Pasadena, Calif. Dr. Clark B. Millikan, California Institute of Technology, was the speaker. He gave a brief history and engineering summary of the tunnel, and following his talk, the members, accompanied by guides, visited the wind tunnel, inspecting the various parts. One hundred and five members attended the meeting.

Metropolitan Section Forms New Jersey Program Division

First Meeting on October 24

THE Metropolitan Section of the Society has broadened its program activities in order to better serve and widen its usefulness to its large membership and is sponsoring a number of specially designed meetings for those members working or residing in the Northern New Jersey area. To accomplish this, the Metropolitan Section Program Committee has formed a New Jersey Division with a committee consisting of G. E. Hagemann, G. W. Nigh, W. S. Johnston, F. P. Brand, and E. J. Billings, with whom is associated J. D. Potter, chairman of the Plainfield Section.

The Metropolitan Section through this Committee has become a member of the Technical Societies Council of New Jersey, a central agency for co-ordinating engineering meetings of various societies in that area, avoiding conflicting dates and bringing to the attention of all engineers, the meetings of all the Societies which are members of the Council.

The first meeting will be held on Wednesday, October 24, 1945, at the Essex House, Newark, N. J., at which J. E. Tobey, director of The Fairmont Coal Bureau will speak on the subject of fuels.

Subsequent meetings will have as their subjects, marine power, shipbuilding, oil refining, power plants, and airplane manufacturing, and materials handling. Inspection trips are planned as features of these meetings.

Student Branches

Alabama Polytechnic Institute Branch

At the meeting on June 9 at Auburn, Ala., two films were shown, one entitled "Sulfur," and the other, "The Power Within."

Election of officers was held at the June 18 meeting in Ramsay Hall, with the following results: Zacarias E. Bendeck, vice-president, and Marco A. Martinez, secretary-treasurer. Bob W. Dean continues as president, and R. Hixon as honorary chairman.

The third meeting of the summer quarter was held on July 30, with members of A.I.E.E.

ZACARIAS E. BENDECK
(Vice-president, A.S.M.E. Student Branch, Alabama Polytechnic Institute, Auburn, Ala.)

and A.I.Ch.E. attending. J. E. Hannum, dean of the Engineering Schools, gave an interesting talk on "Engineering Through the Ages."

California Institute of Technology Branch

At the August 9 meeting held on the campus, the principal speaker was N. A. D'Arcy of the Charles W. Carter Company, Los Angeles, Calif. Mr. D'Arcy, who was himself a student at C.I.T., spoke on the subject of hydraulic couplings and torque converters. He pointed out the differences between these two types of hydraulic machinery and illustrated several applications of each. Following his talk, A. Hollander, member A.S.M.E., an instructor at C.I.T., and consulting engineer for the Byron Jackson Pump Company, explained some fundamental engineering principles which are used in designing hydraulic equipment like fluid couplings and torque converters. After an explanation of the basic ideas, he told the audience that this field of hydraulic couplings is very new and still needs improvement.

University of Cincinnati Branch

The last business meeting of the season was held on August 1 in Baldwin Hall, when the following officers were elected for the coming year: R. E. Lippert, president; R. Powell, vice-president; W. H. Friedlander, secretary, and F. R. Armstrong, treasurer.

Columbia University Branch

The second meeting of the current semester on August 24 at the Engineering Building, featured R. F. Gagg, vice-president A.S.M.E., and assistant general manager of Wright Aeronautical Corporation, Paterson, N. J. Mr. Gagg explained the structure of the A.S.M.E. and its meaning to student engineers. He then presented a film, "The Powerhouse of Aviation," which illustrated the application of high-speed, multipurpose machines to high-precision parts that are required in a modern airplane engine.

Duke University Branch

After a short business meeting on July 24, during which plans for an inspection trip to a near-by industrial plant were discussed, a talk on railroading was given by Nash Love, a junior mechanical engineer, and student member. He told of the relative merits of steam and Diesel power as applied to rail transportation, and related some of his personal experiences while employed as a fireman on both steam and Diesel locomotives by the Atlantic Coast Line Railroad, and as water tender on board a Navy transport in the Pacific.

Officers for the current semester are: F. A. Shomaker, president; S. D. Ranon, vice-president, N. M. Love, secretary, and J. J. Geier, treasurer.

Cornell University Branch

Two meetings were held in July. At the July 20 meeting the advantages of becoming a member of the student branch of A.S.M.E. were presented so as to acquaint the nonmembers as well as the members with the value of the Society to them. A film entitled "The Making and Shaping of Steel" was presented. This film showed the entire story of the production of steel and steel products from the mine through the various phases of processing and forming, to the final finished product. On July 28 a film entitled "Pumps" was shown. This picture covered various types of rotating pumps that are encountered in engineering, gave their principal advantages, and showed how these qualities make it desirable to use each particular pump for a specific job. A second film illustrated the combustion process in a Wright Cyclone engine. Although the film covered this product specifically, and also the airplane industry, it was general enough to be applied to all internal-combustion engines. By showing how the various deviations in combustion affect the operation of the engine, and consequently the plane, the point in question was made very clear.

University of Michigan Branch

The first meeting of the summer semester was held on July 25 at Michigan Union. The program consisted of a film "Cyclone Combustion" made by the Wright Aeronautical Corporation.

Frank Amon was unanimously elected vice-president to fill the unexpired term of the former vice-president who had left college. Several announcements were made by Professor Schwartz, honorary chairman. Several committees were appointed to carry out plans for future meetings.

A second meeting was held on Aug. 22 at Michigan Union, when a film entitled "Milling Machines," was shown. September 7 was chosen as the date for a picnic to be held at the Arboretum.

Pennsylvania State College Branch

On August 23 at the meeting held in the Main Engineering Building, W. H. Fenton, a student member, gave a talk entitled "Raising of the U.S.S. Lafayette." Another member, R. Craig, spoke on "Gas Turbines."

Purdue University Branch

Two films were shown at the August 28

(*Top row, left to right:* B. Larsen, R. J. Hallbach, J. Beam, W. Thornton, F. Kimmel, W. Luehrs, J. Delaney, T. Blim, R. Golze, R. Bojanowski, S. Abramovitz, I. Alloy, A. Dimoff, L. Brown. *Middle row, left to right:* A. Caliendo, E. L. Bell, J. Eckerly, H. Dubin, A. Aasen, G. Habenicht, H. Bordeaux, J. Enander, J. Gioler, D. Martin, Jr., E. Kleinczak, B. Brille, W. Fiech, R. C. Arens, E. Arends, W. A. Bickness. *Front row, left to right:* E. Goetach, W. Cook, P. Keller, W. Erickson, R. Budenholzer, S. Winston, O. Nelland, R. Ahlgen, L. S. Baness, W. Atchison, E. Donkers, and E. Hoppe.)

(*Top row, left to right:* D. Albert, S. Sexson, S. Mayster, J. Vieceli, A. Strong, A. Waite, R. Ronk, R. Sweiger, J. F. Schmidt, R. Thurston, K. Milbradt, R. Schimmelpfenig, C. Young, D. Wing, A. Marcussen, C. Mazarakio, N. Stern, M. Stidham. *Middle row, left to right:* R. Negele, H. Thomiszer, T. Knepper, R. Fries, R. Novy, A. Nupnau, L. Jatczak, R. L. Olson, R. Sahlstrom, J. Noble, M. Spector, D. Meyers, T. Zaggy, A. Troyan, P. Parlos, L. Mann, R. DeBoo. *Front row, left to right:* H. Mueller, J. Pocock, F. Pasek, C. Porter, R. Paulsen, D. Roesch, G. Martin, H. Nachman, W. D. McThomas, Jr., T. Moran, J. H. Schmidt, J. Burns, T. Ruck, and A. Spooner.)

A.S.M.E. STUDENT BRANCH, ILLINOIS INSTITUTE OF TECHNOLOGY

meeting at the Mechanical Engineering Building. The first, "Diesel, the Modern Power," explained and illustrated the fundamental principles of Diesel-engine operation. The second, "Diesel Engine Governors," illustrated the principles underlying the governing of Diesel engines and showed details both on the overspeed and regulating types of governors.

Officers elected for the coming year are: W. M. Byerley, chairman; G. W. Barnes, A. W. Brooks, J. H. Colby, and H. H. Hirschl, vice-chairmen; and C. W. Kay, secretary-treasurer.

Rensselaer Polytechnic Institute Branch

A meeting was held on Aug. 2 in Russell Sage Laboratory for the purpose of introducing to freshmen some aspects of the field of mechanical engineering. Two films were shown, "Salvaging and Supercharging of Diesels," and "Mechanical Refrigeration." A committee was named to offer nominations for the election of officers to be held in the near future.

Rutgers University Branch

On Aug. 30 a meeting was held for the express purpose of reviving interest in the student A.S.M.E., as the University expects to start in a few weeks its first good-sized engineering freshman class since before the war. Thirty-two soldiers from the A.S.T.P. attended the meeting. A Bakelite film entitled "Four Kingdoms," was shown as part of the program.

University of Southern California Branch

L. V. Leonard, mechanical engineer, Shell Oil Company, gave an interesting talk on the Reynolds Number at the July 25 meeting in Harris Hall auditorium. Five members from the Los Angeles, Calif. Section were guests.

A.S.M.E. STUDENT BRANCH, RENSSELAER POLYTECHNIC INSTITUTE

(*Top row, left to right:* J. Lisankie, T. Forbes, L. Weinberg, J. Keyes, W. Heck, M. Grele, D. Spetta, R. Jordon, H. Hilberg. *Middle row, left to right:* E. Blanch, R. Gamble, M. Goldstein, R. Abrams, W. Wales, K. Stetson, S. Tuthill, W. Hicks, R. Kennison, H. Scagnelli. *Front row, left to right:* D. Neale, R. Van Horn, R. McWorter, C. Morrison, treasurer; I. Kosecoff, chairman; R. Wick, secretary; B. Murdock, F. Bellow, and B. Cahill.)

A.S.M.E. YALE UNIVERSITY STUDENT BRANCH

On Aug. 21 the members attended the Los Angeles Section dinner and inspection-trip meeting at Pasadena, Calif. Dr. Clark B. Millikan, professor of aeronautics at the California Institute of Technology, and director of the Southern California Co-Operative Wind Tunnel, was the speaker. He explained the technicalities and problems of the wind tunnel. Following his talk, an inspection trip was made to the control room, and the testing room of the tunnel, as well as an inspection of the equipment used for testing.

Another inspection trip, sponsored by the Los Angeles Section, was made on Aug. 25 to the Union Oil Wilmington Refinery. Mr. Meyers, engineer at the refinery, gave an introductory talk on the plant layout and the processing of the crude oils. Guides conducted the members through the plant and showed cracking units, refining process tanks and equipment. The knock-testing laboratory was also observed where fuels were tested and rated.

Two motion pictures were shown at the Aug. 30 meeting in the Cinema Building, entitled "Refrigeration and Ice-Making," and "Diesel, the Modern Power."

Tufts College Branch

The first meeting of the summer term was held on July 11 at Robinson Hall, under the direction of David A. Fischer, honorary chairman. New officers elected at this meeting were: Russell E. Goodman, president; Jacob Gleber, vice-president; and Leroy H. Froeberg, secretary-treasurer. Plans were discussed for future meetings and a program committee was appointed to arrange for scheduled engineering trips during the next few months.

Tulane University of Louisiana Branch

At the meeting on August 6 in the Engineering Building, Prof. A. M. Hill, professor of heat engineering, was elected faculty adviser. Members were appointed by the chairman to serve on various committees for the coming semester. The program consisted of two papers given by student members; the first, "Fatigue Stresses," was read by William Frearing; and the second, "Sugar Processing," was presented by Preston Mottram. The latter was awarded a prize of $2.

Creese Named President at Drexel

JAMES CREESE, vice-president of Stevens Institute of Technology since 1928, has been elected president of Drexel Institute of Technology, Philadelphia, Pa. He will assume the office on Oct. 1, 1945.

President's Page

Organizing the Engineering Profession

THROUGHOUT the years the formation of a top engineering society that would properly represent all branches of the profession has been proposed and discussed. Attempts have been made to bring about such an organization, but, unfortunately, all have failed for a variety of reasons.

Much has been written on this subject in the past but most discussions have been confined to expressions of personal opinion. While it has been generally agreed that a top organization is desirable, wide differences of opinion on the methods of attaining the desired end always exist. Agreement on methods must be based on a well-organized and objective study of the subject.

To conduct such a study the Joint Conference Committee, whose membership is made up of the officers of the four Founder Societies and the American Institute of Chemical Engineers, has appointed a committee which will report before the end of the year. It is confidently expected that the report will recommend practicable ways and means of bringing about the desired consolidation of the various societies representing the engineering profession. Opportunity will then be afforded the entire profession for full discussion and consideration of the proposals.

While rumors have sprung up that this, that, or some other form of organization will be specifically recommended, such rumors are without foundation in fact. It is hoped that members of all engineering societies will exercise patience until the report is made public and will then consider the recommendations with open minds.

Only by wise planning and a wholehearted determination on the part of all engineers to make the finally approved plan work can we expect to set up a vigorous, useful, and truly representative organization for the engineering profession.

(*Signed*) Alex D. Bailey, *President*, A.S.M.E.

Booklet "Diesel Facts" Now Available

GROWING demand for Diesel engines for producing the power in municipally owned power plants is revealed in a new booklet published by Diesel Engine Manufacturers Association. Covering the use of Diesels in city power plants, the booklet is the first of a series to be issued by the association under the general title, "Diesel Facts."

A special section of the booklet treats of the procedure to be followed by a city that wants to have its own power plant. Another section outlines the widespread use of Diesel engines in the generating projects of the Rural Electrification Administration.

A survey of potential peacetime uses of Diesel engines has been made by Diesel Engine Manufacturers Association. During the war, the government has been using practically all of the Diesel-engine output for propulsion in ships and boats, and for electric generating sets to be sent overseas. Now that the war demand is over, the industry will naturally turn to its prewar markets. The first of these markets to be explored by the association is the field of municipal light and power plants.

Future booklets to be issued by the Diesel Engine Manufacturers' Association will deal with Diesel-engine applications in ships and boats, locomotives, the oil industry, and various stationary usages.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York 8 West 40th St. | **Chicago** 212 West Wacker Drive | **Detroit** 109 Farnsworth Ave. | **San Francisco** 57 Post Street

MEN AVAILABLE[1]

PLANT MANAGER, over 30 years' experience in all phases of manufacturing, mostly in small-parts mass production; now engaged in consulting management engineering; desires permanent location with future; East preferred. Me-926.

EXECUTIVE MECHANICAL ENGINEER with extensive experience in product design, development and experimental. Automotive and allied products. Creative ability. Present position on defense work expiring shortly. Desires responsible position with progressive organization. Me-927.

MECHANICAL ENGINEER, 27, honor graduate, registered professional engineer, 5 years' experience in design, development, and testing of internal-combustion-engine power plant. Any location in world will be considered, but connection with American firm who wishes to establish sales and service organization in Canada or add to their present service is preferred. Me-928.

GRADUATE MECHANICAL ENGINEER, M.S., married, 25, desires permanent design or development engineering position. Two and a half years' experience as development engineer on jet-propulsion machinery; one year in charge of large testing program. Earlier experience with steam power plants. Available September 20. Pacific Coast preferred. Me-929.

SALES ENGINEER, experienced stokers, machinery, instruments, and valves. Can select distributors and follow. Prefer East. Me-930.

EXPERIENCED CHIEF DESIGNER, young, with proved creative ability in design of automatic machinery utilizing mechanics, hydraulics, and electronics; administration and supervision of engineers and machinists in the development, construction, and installation of such high-production machinery. Me-931.

VICE-PRESIDENT of large corporation seeks new connection in New York City. Offers exceptional ability for organization, planning, production. Broad engineering experience includes power plant, refrigeration, real estate, building operation, candy and container manufacture, ship and engine repair. Me-932.

MECHANICAL ENGINEER, 33, M.S. degree; registered professional (Ohio); 11 years' broad experience in general engineering, college teaching, design, research, and development. Now chief of design and development section of government arsenal. Desires position of responsibility. Me-933.

MECHANICAL ENGINEER, 27, with five and a half years' experimental and development testing of aircraft engines, desires position in engine or equipment testing and development. Location in West or Midwest preferred. Me-934-2120-Chicago.

PRODUCT ENGINEER, graduate mechanical, age 38. Six years design and development on rubber vibration-absorption mounts, 7 years' diversified experience in Ordnance production, metallurgical laboratory, gas utility. Prefer East Coast. Me-935.

EXECUTIVE OR REPRESENTATIVE, 40; substantial engineering background includes research, development, design, construction, in aviation and process industries; 12 years commissioned service Air Corps, Navy, Naval Reserve; Annapolis graduate. Me-936.

MECHANICAL ENGINEER, B.S. Experienced in mechanical design engineering work in connection with development of vacuum tubes and pumps. Me-937.

EXECUTIVE, graduate mechanical engineer; 28. Five years' successful experience supervising design and manufacture of precision machinery. Now chief mechanical engineer eastern electrical manufacturer. Desires similar position Pacific Coast. Available November. Me-938-458-D-6 San Francisco.

MECHANICAL ENGINEER, four years' test, field, and design experience in steam turbines and electrical equipment, desires position with progressive organization in power generating, process, or chemical industry. Me-939.

GRADUATE MECHANICAL ENGINEER, 27, married. Five years' diversified experience in chemical-plant maintenance, construction, and design. At present in charge invention and development of small mechanisms. Particularly interested in Middle West. Me-940.

POSITIONS AVAILABLE

CENTRIFUGAL PUMP DESIGNER, experienced, with background in hydraulics and with thorough knowledge of mechanical design of double-suction, axial-flow and multistage centrifugal pumps. Permanent. Write giving full details of education, experience, present, and expected salaries. Upstate New York. W-5679.

MECHANICAL ENGINEER, particularly experienced in plant maintenance, piping, power, modernizing and new construction. $6000–$7500 a year. Ohio. W-5727—D-2405 (*c*).

MECHANICAL ENGINEER, about 35, to act as assistant chief engineer. Must have industrial experience in heavy manufacturing industry; also some supervisory duties. Some experience with industrial-plant construction would be desirable although not prerequisite. Baltimore, Maryland. W-5873.

MECHANICAL ENGINEERS with 6 to 12 years' experience involving supervision of high-production machine shop requiring close tolerance; or one having been responsible for fabrication tool design, process specifications, or inspection gage design. Should be familiar with welding practice. Tennessee. W-5881.

ENGINEERS for manufacturer of automotive accessories. (*a*) Chief engineer, 35–45, mechanical or electrical graduate preferred, with experience in organization and systematizing of departments handling new-product developments, tool, die, jig and fixture design, and production engineering. Should have knowledge of applications of heat transfer and electronics (infrared heat and light). Must train and supply technical assistants for sales departments; should be abreast of metallurgical developments. $10,000–$12,000 year. (*b*) General superintendent, 35–45, technical graduate preferred, with proved ability to handle an organization of at least 500 men.

[1] All men listed hold some form of A.S.M.E. membership.

Must have considerable experience with deep drawing and stamping of ferrous and nonferrous sheet metal; metal assembling and finishing, including soldering, brazing, welding, etc.; also experience in handling personnel problems and office procedures. $8000-$10,000 year. Michigan. W-5884-D.

DESIGNER with considerable drafting experience to design and lay out automatic package machinery for food manufacturer. $6000-$7500 a year. Headquarters, New York, N. Y. W-5890.

MASTER MECHANIC, 30-45, for company whose business is printing, processing, dyeing, and finishing of all textiles. Should have some textile experience. Will be entirely responsible for maintenance, repair, and upkeep of all equipment, both mechanical and electrical. Would also be responsible for all construction and yard work, and understand the transmission of steam and power. Will have maintenance crew of approximately 60 men, including mechanics, carpenters, electricians, masons, and laborers. Salary open. Excellent opportunity. New England. W-5891.

INSTRUCTORS of mechanical engineering including heat power, mechanics, and strength of materials and machine design, for classroom and laboratory work. One or two-year appointments. Upstate New York. W-5904.

PURCHASING ASSISTANT, under 40, mechanical or chemical-engineering graduate preferred, with oil-refining or chemical-equipment purchasing experience, for process manufacturing plant. $4000 year. Connecticut. W-5915.

FACTORY SUPERINTENDENT, young, for paper plant. Must have experience in manufacture of fine paper. Should be good executive as man will have complete charge of plant. Company employs about 200 people. Salary open. Michigan. Interviews, New York, N. Y. W-5916.

INSTRUCTOR OR ASSISTANT PROFESSOR for department of industrial engineering and engineering drawing. A degree in industrial engineering as well as some practical experience is required as applicant will teach industrial-engineering subjects along with engineering drawing. Salary, for nine months, $2000-$2400 year. Opportunity to teach one six-week term during summer. Southwest. W-5919-C.

DESIGNER, mechanical graduate, with considerable textile-machinery experience, to design and lay out narrow ribbon looms. $5000-$6000 year. Pennsylvania. W-5924.

MECHANICAL ENGINEER, 30-40, with power-plant experience, for design, construction, and maintenance of power plant; both steam and electric. $5100-$5400 year. Permanent. Location: one year in New York, then transfer to Texas. W-5930.

ENGINEERS. (*a*) Manufacturing manager with broad experience in mass production of small parts, molding, screw machines, punch presses, assembly and tooling, to take full charge of manufacturing. $7000 year. (*b*) Chief mechanical engineer to take complete charge of all production and design engineering. $7000 year. (*c*) Mechanical engineer to head drafting and tool-design departments. Work involves design of tools, dies, jigs, and fixtures; development of production machines and supervision of machine shop. Should be thoroughly experienced in large variety of small parts. $5000-$6000 year. (*d*) Die designer for designing deep-drawing dies for metal. $3600-$4800 year. Pennsylvania. W-5944.

SUPERINTENDENT with 15 years' experience in supervision of light metal stamping production, for small manufacturer. Must be capable of doing necessary tool and die design. $6000 year. New York, N. Y. W-5954.

MECHANICAL ENGINEER, 30-35 preferred, to prepare plans and specifications for installations, in industrial and commercial buildings, of heating and ventilating, plumbing and other piping trades, electric light and power wiring, air conditioning; prepare estimates of cost of such installations, either from his own designs or from those of other engineers; supervise such work being performed by subcontractors. Must have administrative ability to employ and direct assistants and specialists. $5000-$6000 year. Ohio. W-5961-D.

MECHANICAL ENGINEERS to have working knowledge of statistics of high-load-density structures and broader experience in dynamics, preferably including pneumodynamics; who has record in machine developments involving solution of the complex problems of ultra high mass velocities and accelerations by use of special materials and techniques. $4000-$6000 year. Permanent. New England. B-689(*a*).

A.S.M.E. Local Sections

Coming Meetings

Bridgeport. October 4. Bridgeport, Conn. Subject: "Recent Work in Forging Research," by Dr. W. Trinks, Projects Director, A.S.M.E. Research Committee on Forging of Steel Shells and Demolition-Bomb Bodies, Pittsburgh, Pa.

Chicago. October 3. Northwestern Technological Institute, Evanston, Ill. Dinner at 6:30 p.m. in dining room A, Scott Hall at Sheridan Road and University Place, Evanston, Ill. This will be a joint meeting of the Applied Mechanics Division and the Mechanics Colloquium. Chairman, Prof. M. F. Spotts, Northwestern Technological Institute.

October 18. Junior Engineers' Meeting. Speaker, W. J. King, Battelle Memorial Institute. Subject: "Human Relations for Engineers." Place and time to be announced later.

October 22. Dinner meeting at 6:00 p.m., Electric Club, 38th floor, Civic Opera Building, Chicago, Ill. Meeting sponsored by the Industrial Instruments and Regulators Division. Subject: "Industrial Instruments and their Application," by Dr. John J. Grebe, director of the Physical Research Laboratories of the Dow Chemical Company, Midland, Mich.

Hartford. October 3. Hartford, Conn. Subject: "Recent Work in Forging Research," by Dr. W. Trinks, A.S.M.E. Lecturer, Pittsburgh, Pa.

Inland Empire. November 2. Spokane, Wash. Subject: "Engineering—The Modern Covered Wagon," by Captain A. A. Nichoson, vice-president, The Texas Company, New York, N. Y.

Oregon. October 29. Portland, Ore. Subject: "Engineering—The Modern Covered Wagon," by Captain A. A. Nichoson, vice-president, The Texas Company.

Providence. October 2. Informal dinner at the University Club; meeting at 8:00 p.m. in the rooms of the Providence Engineering Society, 195 Angell St., Providence, R. I. Subject: "Recent Work in Forging Research," by Dr. W. Trinks, A.S.M.E. Lecturer, Pittsburgh, Pa.

San Francisco. October 25. Engineers Club of San Francisco, San Francisco, Calif. Captain A. A. Nichoson, vice-president of the Texas Company, will address the members.

Southern California. October 18. Los Angeles, Calif. Captain A. A. Nichoson, vice-president of the Texas Co. of New York City will address the Section members.

Utah. October 15. Salt Lake City, Utah. Captain A. A. Nichoson, vice-president of the Texas Company, will address the members. Subject: "Engineering the Blueprint of the Postwar World."

Western Washington. November 1. Seattle, Wash. Subject: "The Postwar Era," by Captain A. A. Nichoson, vice-president of the Texas Company.

Worcester. October 5. Worcester, Mass. Subject: "Recent Work in Forging Research," by Dr. W. Trinks, A.S.M.E. Lecturer, Pittsburgh, Pa.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after October 25, 1945, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Re-election; Rt = Reinstatement; Rt & T = Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Member, Associate, or Junior

ALBERT, PETER W., Waterbury, Conn.
AXTELL, FRANK F., Port Neches, Texas
BAKER, H. DEAN, New York, N. Y.
BASSETT, H. N., Buenos Aires, Argentina
BISSHOPP, K. E., Chicago, Ill.
BREECE, GRADY LEE, New Orleans, La.
BRONSON, RANDOLPH WARD, Ozone Park, N. Y.
BUNCE, JOHN PETER, Milwaukee, Wis.
CALDWELL, I. M., Tulsa, Okla.
CAPELL, JOHN E., New York, N. Y.
CARNEY, H. RAYMOND, Wilmington, N. C.
CARTER, PRESTON D. (MAJOR), Detroit, Mich.
CHAO, W. W., Whitinsville, Mass.
CHAUVIN, LEO T., Hampton, Va.
CONN, J. BART, Chicago, Ill. (Rt & T)
COX, THOMAS P., Cuyahoga Falls, Ohio

DAGUE, ARTHUR D., San Francisco, Calif.
DAVIS, HUNT, Jeannette, Pa.
DESHPANDE, D. L. (CAPT.), Travancore, India (Re)
DIETZ, W. F., Bethesda, Md.
DODD, SAMUEL T., JR., Los Angeles, Calif. (Rt & T)
DUBOFF, JACK I., Peoria, Ill.
DUFFY, JAMES J. (LIEUT.), c/o A.P.O., San Francisco, Calif.
EUVRARD, LEROY, New York, N. Y.
FEDERMAN, SAMUEL, New York, N. Y.
FINLEY, F. A., Baltimore, Md.
FORD, HARRY, Westport, Conn.
GADZUK, JOHN, Drexel Hill, Pa.
GEER, ROGER L., Ithaca, N. Y.
GIBNEY, JAMES J., JR., Schenectady, N. Y.
GRANDINETTI, JOHN R., Philadelphia, Pa. (Rt)
GRAVES, COLBURN R., Garden City, N. Y. (Rt & T)
GROENE, WILLARD L., Cincinnati, Ohio
GROSSMAN, MARTIN L., Blacksburg, Va.
GUNDERSON, L. O., Chicago, Ill.
HALDEMAN, WILLIAM A., Ilion, N. Y.
HANSEN, WALTER R., Salt Lake City, Utah
HARPER, JOSEPH J., Lansdowne, Pa.
HAYES, FRANK O., St. Paul, Minn.
HEGGE, J. I., JR., Upper Montclair, N. J.
HEMMERLE, GEORGE F., Philadelphia, Pa.
HENDERSON, JACK R. (LIEUT.), Brookley Field, Ala.
HICKSON, WM. M., Cincinnati, Ohio (Rt & T)
HILL, CHARLES S., JR., Philadelphia, Pa.
HINCKLE, DON A., Columbus, Ohio
HOWE, THOMAS B., Brooklyn, N. Y.
HUNICKE, AUGUST B., JR., Great Neck, N. Y.
KATZ, MAURICE, Roxbury, Mass.
KAVENY, J. GORDON, Little Falls, N. J.
KORNYLAK, ANDREW, Jersey City, N. J.
LAND, MALCOLM L., Jeannette, Pa.
LASLEY, JAMES B., Wilmington, N. C.
LOEFFLER, ALFONS G., Norwalk, Conn.
LYON, DANIEL R., Chicago, Ill. (Rt & T)
MACK, HAROLD D., JR., Hawthorne, N. Y.
MATLAT, G. W., Baltimore, Md.
MAY, JAMES EDWARD, Pensacola, Fla.
MCBRIDE, EDWARD J., Wellsville, N. Y.
MCCUBBIN, JOHN D. S., Brooklyn, N. Y.
MCGINNIS, JAMES G., Coatesville, Pa.
MENDELSON, ALEXANDER, Cleveland, Ohio
MERCHANT, M. EUGENE, Cincinnati, Ohio (Rt & T)
MONNIER, RENE A., Palisades Park, N. J.
MUELLER, ALFRED C., Wilmington, Del.
OLSON, DONALD R., New Haven, Conn.
OSBORN, OLIVER, Freeport, Texas
PARKER, GEORGE A., Baldwin, N. Y. (Rt & T)
PENDRAY, G. EDWARD, Crestwood, N. Y.
PETERSEN, FRANK F., Los Gatos, Calif.
PROWELL, ROY W., Pittsburgh, Pa.
PRYOR, WILLIAM A., Savannah, Ga.
RANKIN, DAN R., Los Angeles, Calif.
RAPP, PHILIP C., Buffalo, N. Y.
RICHARDSON, P. H., Huntington, N. Y.
ROBINSON, JOHN T., New York, N. Y.
ROUBIK, JOSEPH R., Milwaukee, Wis.
RUBINSTEIN, MARTIN A., Hightstown, N. J.
SAUSELE, GEORGE J. H., Arlington, Va.
SCHMIDT, RALPH, Kingston, Ontario, Can.
SCHMIDT, ROGER W., New York, N. Y.
SCOTT, WRAY M., Omaha, Nebraska
SEYMOUR, EDGAR D., Rochester, N. Y.
SHEA, THOMAS M., Philadelphia, Pa. (Rt & T)
SMILEY, EDWIN, Drexel Hill, Pa. (Rt)
SMITH, EDWARD A., Chatham, N. J.
SOLOMON, JOHN W., New York, N. Y.
SPENCE, STANLEY F., New York, N. Y.
SPRARAGEN, WILLIAM, St. Albans, N. Y.
STEGLICH, HERBERT H., Wilmette, Ill.
TEMPLE, EDWARD A., Baltimore, Md.
VERITY, C. E. H. (GROUP CAPT.), New York, N. Y.
VOLICK, E. G., Windsor, Ontario, Canada
WICHER, WILLIAM E., Washington, D. C.
ZWACK, RAYMOND T., West Caldwell, N. J. (Rt & T)

CHANGE OF GRADING

Transfers to Fellow

CHAMBERS, W. R., Oak Ridge, Tenn.
FRANZ, FREDERICK L., West Haven, Conn.
GILBRETH, LILLIAN M., Montclair, N. J.
KELLER, FRED J., Huntington Bay Hills, N. Y.
PROUTY, FRANK H., Denver, Colo.
TERRY, ROGER V., Newport News, Va.
TRUE, CHARLES H., Chicago, Ill.
TUTTLE, WILLIAM B. (COL.), San Antonio, Texas

Transfers to Member

AARON, ROBERT H., Los Angeles, Calif.
BELLINGER, LORENTZ D. (COMDR.), Huntington, W. Va.
BENEDICTUS, ANDREW R., Washington, D. C.
BOSLER, KRELL, Cincinnati, Ohio
BROWN, LAWRENCE W., West Somerville, Mass.
COLLORA, N. A., Terre Haute, Ind.
COOPER, W. B., Rome, Ga.
COTTER, GEORGE L., Winnetka, Ill.
DOGGETT, JOHN, JR., Houston, Texas
DOROW, RAY O., Kansas City, Mo.
ELY, ROBERT E., Bakersfield, Calif.
ENO, W. S., Murray Hill, N. J.
FISHER, DAVID A., West Medford, Mass.
FORSMAN, ELMER J., Atlanta, Ga.
FOSTER, ALBERT C., Westfield, N. J.
GRACE, CHARLES T., Ames, Iowa
HANKES, ELMER J., Minneapolis, Minn.
HIRSCH, S. R., Utica, N. Y.
JANAS, LEO J., Chicago, Ill.
JANCO, NATHAN, Tulsa, Okla.
KEARNEY, THOMAS J., Detroit, Mich.
KELLY, HOWARD A., Wheeling, W. Va.
KRAUS, MILTON N. (LIEUT.), New York, N. Y.
LEE, JOHN A., Dallas, Texas
LONDON, A. L. (LIEUT.), Alexandria, Va.
MCKNIGHT, EDWARD W. (LIEUT.), Butler, Ala.
MESSERSMITH, ELDON M., Ferndale, Mich.
MILLER, ARTHUR M., Hoboken, N. J.
MITCHELL, J. F. (CAPT.), Rockford, Ill.
OSTWALD, RICHARD, Easton, Pa.
PARKER, LUTHER M., Wellsville, N. Y.
PHILLIPS, PHILIP H., New Castle, Ind.
PRUDDEN, ORRIN D., Woodbridge, N. J.
RUTHERGLEN, JOHN A., Portland, Oregon
SHARL, JOHN, Staten Island, N. Y.
SHEETS, HERMAN E., Greensburg, Pa.
TAYLOR, W. F., Oshawa, Ontario, Can.
WADE E. ANNESLEY, Butler, N. J.
WATSON, M. P., New Orleans, La.
WEEKS, DAN E., Berkeley, Calif.
WENDT, LELAND A., St. Louis, Mo.
WESTENDORF, CHARLES L., Wilmington, Del.
WILLIAMS, ERVIN MAURICE, Spartanburg, S. C.
WILMER, JOHN WHITTINGHAM (LIEUT. COMDR.), Ruxton, Md.
YARYAN, HOMER L., JR. (LIEUT.), Toledo, Ohio
ZARNOWSKI, FRANK J., Harrison, N. J.

Transfers from Student Member to Junior.......59

1945 A.S.M.E. Memorial Biographies Sent on Request

MEMBERS of The American Society of Mechanical Engineers who wish to receive a copy of the 1945 Memorial Biographies of Deceased Members are requested to fill out and mail the accompanying form, or order by letter, addressed to the Secretary, A.S.M.E., 29 West 39th Street, New York 18, N. Y.

These Memorial Biographies, which will be published in October, will form a part of the Society Records Section of the Transactions as bound for library use.

A.S.M.E.
29 West 39th St.
New York 18, N. Y.

Please send me a copy of the October, 1945, issue of Memorial Biographies.

NAME.................................

ADDRESS.................................

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A.S.M.E. Transactions for September, 1945

THE September, 1945, issue of the Transactions of the A.S.M.E., which is the *Journal of Applied Mechanics*, contains:

TECHNICAL PAPERS

- Direct Analysis of Mechanical Wave Filters, by R. C. Binder
- A New Device for the Solution of Transient-Vibration Problems by the Method of Electrical-Mechanical Analogy, by H. E. Criner, G. D. McCann, and C. E. Warren
- A General Method for Calculating Critical Speeds of Flexible Rotors, by M. A. Prohl
- Fatigue Strength of $5^1/_4$-In-Diam Shafts as Related to Design of Large Parts, by O. J. Horger, T. V. Buckwalter, and H. R. Neifert
- Design of Beams of Long Span and Low Specific Strength, by I. Opatowski
- Cumulative Damage in Fatigue, by M. A. Miner
- Inelastic Buckling of Variable-Section Columns, by Dana Young
- The Theory of Ejectors, by H. G. Elrod, Jr.

DISCUSSION

- On previously published papers by B. Sussholz; C. Schabtach and R. O. Fehr; A. W. Rankin; G. Pickett; M. J. Manjoine; E. G. Keller; N. J. Hoff; R. C. DeHart; and C. Concordia

BOOK REVIEWS